Light and

LIGHTING

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contents

Lighting and Appearances

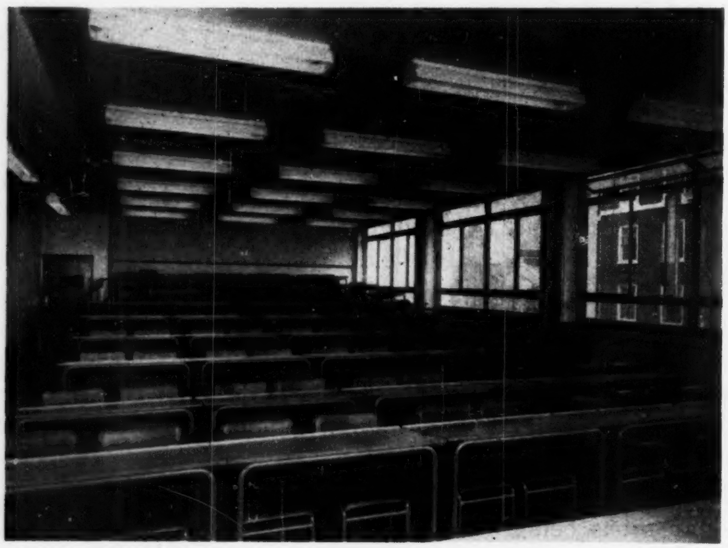
THE design of lighting is in every case a design for appearance—the appearance of some more or less variegated material " field " which is to be " brought to sight." Abstracted from this field, the lighting would be neither good nor bad; neither agreeable nor disagreeable. Such terms have no application to lighting of itself, but only to it as judged by the appearance of what it illuminates. All this, of course, is trite, yet it is easy enough, through using expressions intended to avoid circumlocution, to fall into loose thinking about lighting and to talk about it as if it has attributes which only belong to lighted scenes. The design of lighting for appearances has always been the aim of design (it could not be otherwise) but, nowadays, much more thought is being given to the matter of what the created appearances will be like, and what effects they will have upon the feelings of those who experience them, besides their visual utility. Nevertheless, the latter is fundamental. " It is clear that for the eye, whose office it is to render a true and impartial record of an infinite multitude of closely related points, nothing else is suitable than ... even impartiality of sensation, which never suffers its equable attention to be betrayed into a false distribution by the agreeable or disagreeable nature of the impression." So wrote the philosopher Lotze, but, although we should not generally try to divert attention from the cognitive to the affective excitations of practical sciences, we are right enough to pay due regard in lighting to agreeable appearances.

Notes and News

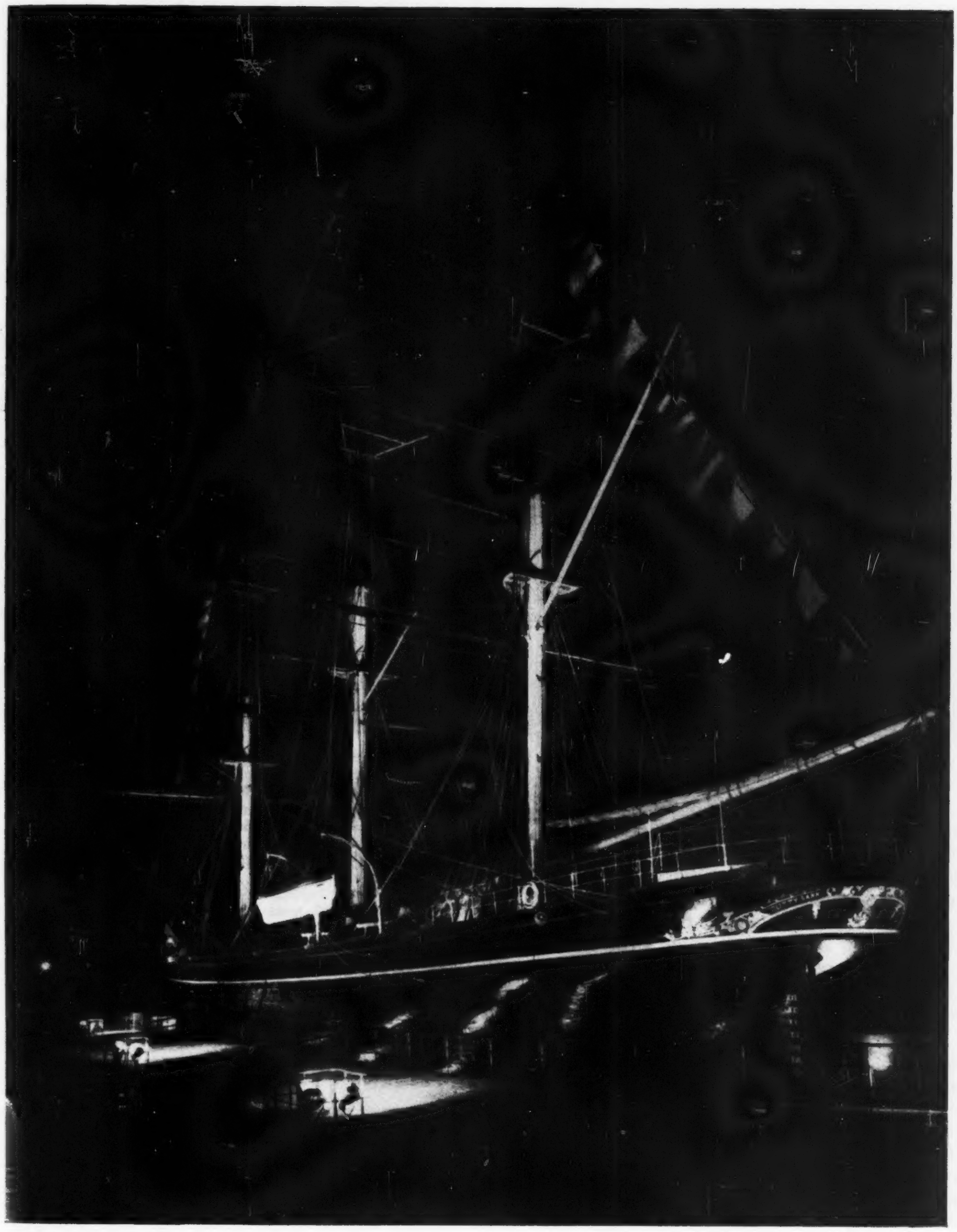
DURING the last few years much progress has been made in the design of school buildings; more recently there has been building activity at various universities (with promise of much more to come) where one would expect the same high standards of design for both exteriors and interiors to be applied. The new Roderic Hill building for the Chemistry and Aeronautics Departments of Imperial College looks most impressive from the outside but the illustration below of a typical lecture theatre shows what can happen inside a modern building. It is hoped that even budding chemists and aeronautical engineers will develop some appreciation of beauty during their training but they are hardly likely to in surroundings such as these. As far as the lighting is concerned there may be some reason why fittings had to be stuck on the ceiling though surely no architect can be unaware of methods of integrating lighting with all the other services he wishes to incorporate in the ceiling. The third illustration of a conference room at the new Students Union Building at Imperial College indicates that we need not despair yet.

Lighting Designer

Every year the Royal Society of Arts awards a bursary for the design of lighting fittings. One would expect the winners to be enticed into the lighting industry, but, having collected their award, they disappear as far as the industry is concerned. One of the winners in recent years, Mr. Maurice Evans, of the Royal College of Art, has now been awarded a £100 prize by the Federation of British Industries to enable him to travel abroad before beginning an industrial career. Mr. Evans says he wants to specialise on the design of domestic equipment, including lighting. Perhaps the industry, which so badly needs designers, will note Mr. Evans's existence and see that he does specialise on lighting. It's high time the industry dipped its hand in its pocket and attracted some of these bright young men.



A typical lecture theatre in the new Chemistry and Aeronautics building at Imperial College; the exterior of the building (top right) would lead one to expect something more interesting. That something better in design and lighting can be done in university buildings is shown by the other illustration of a conference room in the Students Union Building, also at Imperial College, and by the article on pages 232-4.



The 'Cutty Sark'

DESIGNED in the classical style and faced with Portland stone, the Portland Building stands on a stylobate which compensates for the slope of the ground. Terraced walks, flights of steps and formally arranged lawns lead down to the edge of the ornamental lake which the building overlooks. The south elevation, which is 450 ft. long comprises a symmetrical composition, with a central entrance portico crowned with a pediment. The main block is three storeys high, with pedimented gables and a pitched roof. The top storey is set back 9 ft. from the main façade, forming a promenade terrace in the space between.

The flanking wings are two storeys in height, with flat roofs and open balustraded parapets. On the ground floor of each of these wings five semi-circular-arched windows provide access, on the west side, to a paved court and, on the east side, to a balcony. Below the east wing the slope of the ground has enabled the architects to introduce a lower storey, which has five French windows opening on to an enclosed courtyard.

Between the Portland Building and the existing Trent Building is a large piazza, from the north side of which a stone ramp and an external staircase give access to the various departments of the university at the rear. Between the piazza and the west wing of the Portland Building runs a subterranean covered way, 400 ft. long, linking the two buildings. At the rear of the Portland Building a car park has been provided. From it two bridges give access to the first floor of the central block.

Accommodation includes the following: *Central block, lower ground floor,* kitchen and bakery, book shop and book store, recreational rooms; *ground floor,* main entrance hall, secretaries' offices, committee rooms, lecture rooms, games rooms, book shop, stores; *first floor,* men's and women's common rooms, library, locker and toilet facilities, staircase hall (designed to give access in the future to the crush hall of the proposed debating hall building); *mezzanines,* research study rooms, furniture stores; *second floor* (the floor illustrated in this feature), ballroom, dining hall seating 275 persons, suite of private dining rooms, kitchens, stores, serveries, etc.

West wing, ground floor, entrance hall, lecture hall, cloak rooms and toilets; *first floor,* senior common room, library and administrative staff common room; *mezzanines,* caretaker's flat, guest bedrooms. *East wing, lower ground floor,* buttery (with service accommodation and food storage); *ground floor,* entrance hall, cloakrooms and toilets, messroom and common room for maintenance and kitchen staff; *first floor,* art gallery (for public or private display of travelling exhibitions of painting, sculpture, etc.), art library (with separate public entrance, staircase, and foyer), director's office, art studios, safe store for works of art; *mezzanine,* caretaker's flat, guest bedrooms.

The building is constructed mainly in a traditional manner, with load-bearing brick walls faced with stone. The floors (of floating construction, to minimise sound transmission) are supported by prestressed precast concrete beams. The pitched roof is carried by steel trusses and covered with sheet copper on insulation boarding.

The ballroom, with its curved ceiling, lit by concealed cold-cathode tubing, from which are suspended three 25-light chandeliers with "Chrysaline" shades.

Flat roofs, also insulated against heat loss, are covered with asphalt. Windows are vertical sliding sashes, glazed on the main façade with plate glass.

Internally, walls are mainly plastered, and ceilings are of fibrous plaster. Floors are of oak; of maple, on spring-insulated battens in the ballroom and dining hall (where the floors are specially reinforced to counteract rhythmic oscillation); and of large brown "Ruabon" tiling in the buttery.

Heating is from a partial district heating plant, via

Portland Building, University of Nottingham

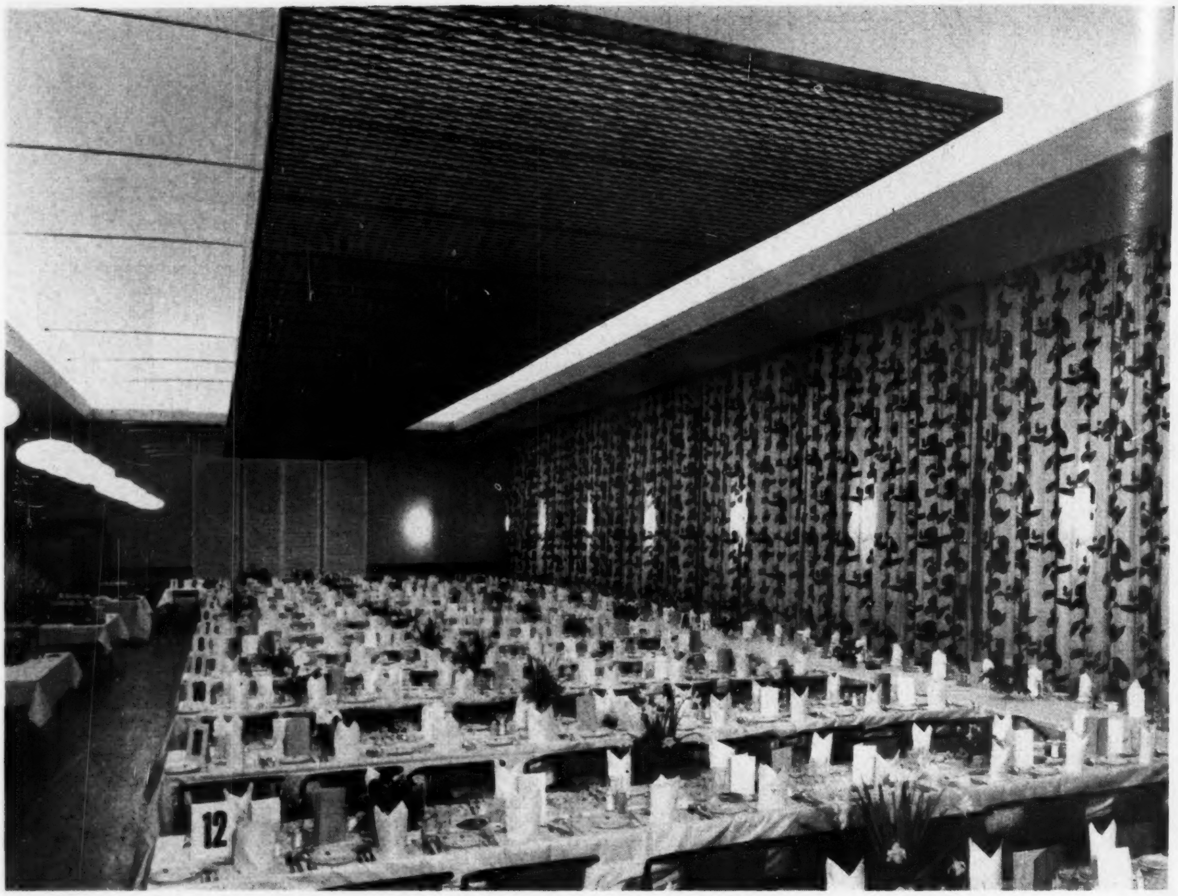
Ballroom, restaurant and private dining rooms

Architects, Cecil Howitt and Partners; consulting architect for internal treatment of accommodation illustrated, John Wright, F.R.I.B.A.; electrical consultant, Prof. H. Cotton, M.B.E., D.Sc., M.I.E.E.; lighting fittings supplied by the General Electric Company, Ltd.

heat exchangers in the east wing. There are radiators in most rooms.

The ballroom has an acoustically treated curved ceiling which is lit by rows of cold-cathode tubing concealed by a cornice around the periphery. Three 25-light chandeliers are suspended from the ceiling, their spherical shades of " Chrysaline " each housing a 60-watt tungsten lamp. Metalwork is of lacquered brass and the arms which support the shades radiate from a walnut centrepiece with a convex mirror on the underside. To prevent these long arms from sagging, there is additional support by means of piano wires fixed to a small knurl on the suspension rod. The shades are hung from the metal arms by white p.v.c. flex.

The annexe to the ballroom, seen on the right of the photograph, is lit mainly by rows of cold-cathode tubing concealed by a fibrous plaster canopy, which is 45 ft. long and is perforated by rectangular-shaped slits. This canopy is suspended by piano wire from the structural elements of the roof, the wires passing through the main ceiling



Above, the restaurant. Suspended below the main ceiling, which is lit by cold-cathode tubing concealed in the cove, is a decorative canopy of raffia. Right, part of the suite of private dining rooms. The groups of "Chrysaline" shades are suspended by silk cord in predetermined patterns.

above. Additional light comes from wall brackets with vertical half-cylinder shades of "Chrysaline."

The dining hall is also lit by cold-cathode tubing concealed, in this instance, in the cove around the raised ceiling. Below part of this ceiling is suspended, again by piano wire, a decorative canopy made of raffia and nearly 80 ft. long. Recesses along the left-hand side of the hall are lit by a row of "Chrysaline" fittings suspended from the ceiling by white p.v.c. flex, while extra light comes from wall brackets similar to those used in the ballroom.

The suite of private dining rooms, which can be subdivided as required by means of flexible screens, are lit by barrel-shaped "Chrysaline" shades suspended by silk cords from white-enamelled metal channels fixed to the ceiling. The arrangement of this channelling determines the patterns created by these decoratively grouped shades.

INTERREFLECTIONS

A guide to their use in lighting design

By A. Dresler, Dr. Ing.

Since 1940 there has appeared an astonishingly large number of publications dealing with various aspects of the theory of interreflection (or interflection as it is called on the other side of the Atlantic). Many of these papers, old and new, are full of complicated-looking formulae, elegant flux-functions, voluminous tables and numerous graphs. The ordinary lighting man may therefore often be at a loss to understand what these interreflections are about and what he would gain if he could make use of them.

It is the purpose of this article firstly to list what the application of the laws of interreflection can help to achieve, then to describe briefly, and as simply as possible, the basic approach to interreflection, and finally to select a method which is comparatively easy to apply yet accurate enough for most practical purposes and which can be used by the lighting engineer in his normal design work whenever he wants to obtain information which orthodox design methods will not reveal.

What "Interreflection" Can Do

(a) The theory of interreflection can be used to determine in artificially lit interiors that amount of illumination on the working plane which is due to light being reflected from and interreflected between the various surfaces of a room. These surfaces are assumed to be perfectly mat, and in themselves of uniform reflectance.

If this reflected and interreflected illumination is added to the illumination reaching the working plane directly from the luminaires the total illumination on the working plane is obtained, and thus :—

(b) coefficients-of-utilisation can be computed for any type of luminaire in the spacing and mounting arrangement actually used.

(c) We can also determine the amount of reflected luminous flux reaching the main surfaces of a room, such as the ceiling, the walls and the floor, and thus

(d) by reference to the reflection factors of these surfaces and the primary incident flux obtain some idea of the gross luminance pattern (Waldram) of the empty interior.

(e) In day-lit interiors the amount of illumination can be determined which is due to reflections from and interreflections between external and internal surfaces. The method is not only applicable to the accepted standard design condition, i.e. the overcast sky, but can also be used to calculate the amount of illumination becoming available through reflected sunlight. (In this article, however, the application of interreflections to natural lighting design will not be dealt with.)

What "Interreflection" Cannot Do

(a) Interreflection does not provide a means of predicting in any detail the actual luminance distribution over any one of the main surfaces, it only gives their average luminances.

(b) It does not take correctly into account the behaviour and influence of such surfaces which are not perfectly mat but more or less glossy.

It should be realised, however, that as far as the interreflection process is concerned, every single surface element of a room interior is exposed to a complete hemisphere of reflected light "above" it. Thus even highly specular surface elements will reflect light which has already passed at least one stage of reflection into a multitude of directions. Small areas of high gloss or large areas of semi-mat finish will therefore not seriously upset the results of the interreflection method.

(c) In common with other methods of lighting design interreflection neglects the influence of furniture and occupants and refers to the empty room.

D. E. Spencer(1) has recently shown that the effect of furniture should normally be quite small (5 per cent. or less). Only when furniture with a highly reflecting top and dark vertical sides is used in a room painted in very light colours and having a floor of high reflectance will the furniture lower the amount of interreflected light appreciably.

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The Basic Approach to Interreflections

If the amount of luminous flux leaving a mat surface is known it is possible to compute how many of these lumens will reach any other surface, be it parallel or at right angles to the emitting surface. The mathematics involved comprise no more than integration over an area. Many authors, e.g., Moon(2), Moon and Spencer(3), Zijl(4), Cadiergues(5) and Phillips(6), to name a few, have dealt with this initial step of the problem in detail.

The resulting lengthy formulae for the transfer of flux from one surface to another can be considerably simplified, if the shape of the room is limited to that of a square room of height h. It was Hisano(7) who first showed that this severe restriction can be tolerated, because the flux distribution in a rectangular room can be treated as being equal to that of the equivalent unit square room of height k, where k is given by $\frac{\text{total wall area}}{4 \times \text{floor area}}$ and therefore becomes

$$\frac{h\ (a+b)}{2\ ab} \quad \text{........................(1)}$$

for a room of width a, length b and height h.

The flux transfer functions for the unit square room were first developed by Yamauti(8) and more recently Phillips(6) prepared a table which gives P_k as a function of k where P_k indicates that proportion of the total flux emitted by the ceiling (or the floor) which reaches the walls.

With the help of this table giving $P_k = f(k)$ it is a matter of simple arithmetic to calculate the illuminations on ceiling, walls and floor which are due to the *first* reflections of the fluxes reaching these surfaces directly from the luminaires. The procedure has then to be repeated for the *second* reflection, and this will give the illumination on the main surfaces due to the "secondary" flux distribution. After that further repetitions would not only be rather cumbersome but are in fact quite unnecessary since the subsequent reflections can be packed together into one process of summation. This process is the same as that used in explaining the functioning of an integrating sphere in photometry. If the illumination values on any one of the surfaces, which are due to the first, the second and all subsequent reflections, are added up, their sum represents the total illumination that becomes available through reflection and interreflection. And from there it is only a simple step to find the corresponding values of reflected luminance.

The reference to the flux transfer functions can be omitted and thus a further considerable simplification achieved if the theory of the integrating sphere is applied straight after the first and not after the second reflection. This was first suggested by Dresler(9) for the determination of the reflected component of daylight and more recently advocated by Croft(10) in dealing with artificial lighting installations.

This method operates as follows: If of the total flux F_l leaving the luminaires F_c reaches the ceiling, F_w the walls, and F_f the floor the total amount of *first* reflected flux will be a fraction a of F_l, i.e.,

$$a\ F_l = F_cR_c + F_wR_w + F_fR_f \quad \text{..............(2)}$$

where R_c, R_w and R_f are the reflection factors of ceiling, walls and floor respectively. Since we are assuming that all the surfaces are mat, $a \cdot F_l$ will be evenly distributed over the whole room and the amount of *second* reflected flux will be: —

$$a\ F_l \times R_{av}$$

where R_{av} is the average reflection factor of all the surfaces of the room, i.e.,

$$R_{av} = \frac{A_cR_c + A_wR_w + A_fR_f}{A_c + A_w + A_f} \quad \text{..............(3)}$$

A_c, A_w and A_f being the areas of ceiling, walls and floor respectively.

The *third* reflected flux is given by

$$a\ F_l \times R_{av} \times R_{av}$$

and consequently F_r, the sum of the first and all subsequently reflected fluxes, will be: —

$$F_r = a\ F_l\ (1 + R_{av} + R_{av}^2 + R_{av}^3 + \ldots) \quad \text{........(4)}$$

This can be written in the form: —

$$F_r = \frac{a\ F_l}{1 - R_{av}} \quad \text{.......................(4a)}$$

or by going back to Equation (2) we get: —

$$F_r = \frac{F_cR_c + F_wR_w + F_fR_f}{1 - R_{av}} \quad \text{..............(5)}$$

The average interreflected illumination E_r will therefore be: —

$$E_r = \frac{F_r}{A} = \frac{F_cR_c + F_wR_w + F_fR_f}{A\ (1 - R_{av})} \quad \text{..............(6)}$$

where A is the total area of the room surfaces, i.e., $A = A_c + A_w + A_f$. As Croft(10) has shown we can eliminate R_{av} and replace it by its components thus avoiding the use of Equation (3), and we finally get: —

$$E_r = \frac{F_cR_c + F_wR_w + F_fR_f}{A_c(1 - R_c) + A_w(1 - R_w) + A_f(1 - R_f)} \quad \text{.....(7)}$$

Equation (7) is the basic formula of interreflection in a simple, yet sufficiently accurate form.

It should be noted that in producing it the number of individual surfaces considered has been limited to the bare minimum. Very often further sub-divisions may become advisable. For instance, in the case of windows not being covered by curtains or blinds it will be necessary to take into account the low reflection factor of the glass panes (approximately 10 per cent.) and to split F_l and A up into four instead of three components.

With the average interreflected illumination available it is a simple step to obtain the average interreflected luminances L_r of the individual surfaces. All we have to do is to multiply E_r with the corresponding reflection factors.

In this way we get: —

$L_{rc} = E_r \times R_c$ for the ceiling
$L_{rw} = E_r \times R_w$ for the walls, and
$L_{rf} = E_r \times R_f$ for the floor.

To obtain the *total* luminances of these surfaces and not just their interreflected component we have to add the amount of luminance which is due to the flux coming directly from the luminaires.

In the case of the ceiling this direct luminance is equal to $\frac{F_c}{A_c}$ R_c and we thus get: —

$$L_c = L_{rc} + \frac{F_c}{A_c}R_c = R_c\left(\frac{F_c}{A_c} + E_r\right) \quad \text{..............(8a)}$$

and correspondingly: —

$$L_w = R_w\left(\frac{F_w}{A_w} + E_r\right) \quad \ldots\ldots\ldots\ldots\ldots (8b)$$

and:

$$L_f = R_f\left(\frac{F_f}{A_f} + E_r\right) \quad \ldots\ldots\ldots\ldots\ldots (8c)$$

(F_c, F_w, F_f in lumens; A_c, A_w, A_f in ft², E_r in lm/ft², and L_c, L_w and L_f in ft.-lamberts.)

As a first and generally permissible approximation E_r can be taken to represent also the average interreflected illumination on the working plane, usually assumed to be a horizontal plane 2 ft. 9 in. or 3 ft. above floor level. If the illumination produced by the flux reaching the working plane directly from the luminaires is added to E_r we get the total illumination E on the working plane. This in turn leads us to the Coefficient-of-Utilisation of the installation which can be written in the following way: —

$$\text{C-of-U} = \frac{E \times A_f \times \eta_l}{F_l} \quad \ldots\ldots\ldots\ldots\ldots (9)$$

where A_f = floor area = area of working plane
η_l = luminaire efficiency
F_l = flux leaving the luminaires.

If we introduce the two components of E into Equation (9) we get: —

$$\text{C-of-U} = \frac{F_{wp} + E_r A_f}{F_l} \times \eta_l \quad \ldots\ldots\ldots\ldots\ldots (10)$$

where F_{wp} is the flux reaching the working plane directly from the luminaires.

Let us now take a second look at Equations (7) and (10) and imagine for a moment that we would like to use them: we shall immediately find that we are up against a serious difficulty. While such items as room dimensions, reflection factors of room surfaces, luminaire flux and efficiency, should be readily available, the vital primary flux distribution (i.e., the values of F_c, F_w, F_f and F_{wp}) is a completely unknown quantity and has to be determined before any use can be made of the theory of interreflection. This applies in every instance and is quite independent of the kind of interreflection data used; it applies to the flux function of Yamauti-Phillips, to the Moon-Spencer interflection tables([11, 12]) and to the formulae given here.

The practical application of the theory of interreflection therefore hinges on the availability of a reliable, yet sufficiently simple method of determining the primary flux distribution over an interior for a given set of conditions, i.e., for the mounting and spacing of a luminaire of known polar distribution.

The Primary Flux Distribution

If the polar distribution curve of the luminaires employed in an installation is known the determination of the amounts of flux leaving the luminaires and reaching the ceiling or the floor, i.e. of F_c and F_f is basically a matter of applying well-known methods of calculation of illumination, such as the inverse square law, the solid angle projection law or the sector flux concept. F_w, the flux reaching the walls, need not be calculated separately, it is obtained by deducting $F_c + F_f$ from F_l. Nevertheless, if one starts doing the calculations from first principles it will soon become apparent that it is a cumbersome, time-consuming process which urgently calls for simplification and some form of preparatory treatment if it is ever to be used in practice.

Several suggestions on how to tackle the problem have been put forward in recent years. If we by-pass partial solutions of the problem, i.e., those limited to a restricted number of types of luminaire ([13, 14, 15, 16]) the first really general and useful suggestion came from Dourgnon([17]). He proceeds along the following lines: For every luminaire installed in the room the ceiling and floor are each divided up into four rectangles in such a way that the corner where these all meet is vertically above the luminaire with regard to the ceiling and vertically below the luminaire with regard to the floor. Fig. 1 shows a typical sub-division of the floor. Then the average luminous intensity I_m of the luminaire within each of the four solid angles occupied by the rectangles (as seen from the luminaire) is computed, separately of course for ceiling and floor. This is done with the help of the polar distribution curve of the luminaire and a table of sets of Russell-angles. (Which set has to be used in any one instance depends on the size and shape of the rectangles and their distance from the luminaire.) The values of I_m obtained in this way for each rectangle are then multiplied by the size of the solid angle ω which the corresponding rectangle occupies as seen from the luminaire. These products of I_m and ω are numerically equal to the luminous fluxes which the rectangles receive from the luminaire. To simplify the determination of the various solid angles Dourgnon gives a comprehensive table from which the solid angles can be read off directly (or by interpolation) as a function of the shape of the rectangle and its distance from the luminaire.

The procedure has to be repeated for every luminaire in the room whose position is not the same with regard to the four corners of the room. This means that in a room with four regularly spaced luminaires (as in Fig. 1)

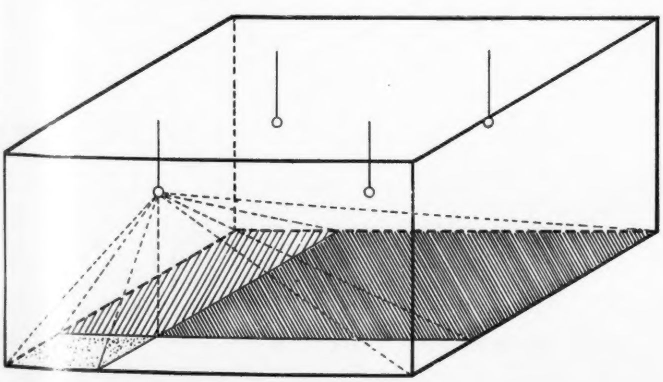

Fig. 1. Typical subdivision of the floor to determine the flux reaching it from one luminaire (after Dourgnon).

only one will have to be considered and the resultant flux on the ceiling (or the floor) to be multiplied by four. With six luminaires in a room two will have to be taken into account, one corner luminaire with a weight of four and one of the two central luminaires with a weight of two.

This brief description of Dourgnon's method should show that his method, although basically sound and straightforward, is still far too complicated to lend itself to frequent application.

The second proposal originated in U.S.A., where Jones and Neidhart[18, 19] introduced the concept of "zonal multipliers" to facilitate the computation of F_c and F_{wp}. The zonal multipliers indicate the average percentages of luminous flux in every 10 deg. zone that strike the reference plane directly. Recently the American IES, through its Committee on Lighting Design, issued an official report[20] which is based on the work of Jones and Neidhart and gives the zonal multipliers for spacing to mounting ratios ranging from 1.0 to 0.4 and for the whole gamut of room indices (A to J) normally encountered in the standard lumen method of lighting design. The tables of zonal multipliers are very easy to use since the sum of the products of zonal flux of the luminaire and corresponding zonal multipliers equals the flux reaching the reference plane.

The IES Report gives a very clear description of the procedure to be followed and should be studied by those interested in a method where the information is presented in tabular form with space left to enter individual results. It should be noted that because the report is concerned with the determination of Utilisation Factors it is not directly interested in the actual primary flux distribution nor in the resulting luminances of the various surfaces, but in the illumination on the working plane. However, the report contains all the information required to arrive at the flux distribution provided one is willing to accept certain limitations imposed by the fact that the diagrams for the reflected flux components refer to a selected number of combinations of reflection factors only.

For those who prefer to remain free of the trammels imposed on them when using a prepared set of tables and diagrams, Croft[21] has provided the answer by using the same Jones-Neidhart Zonal Multipliers and developing them into a very elegant method of determining the primary flux distribution over a room from the polar distribution curve of the luminaires used and the positioning of the luminaires within the room. The method is not only elegant as regards its usability, but also because of the simplifications which Croft has introduced to make his method practicable.

The first step to be taken is to split up the polar light distribution of the luminaire in such a way as to give three component fluxes, viz., the indirect, the horizontal, and the direct flux. The horizontal component is taken to be equal to that of a sinusoidal distribution with the luminaire's horizontal luminous intensity as maximum intensity. The direct component is equal to the flux emitted into the lower hemisphere less half the horizontal component, and correspondingly we get the indirect component by deducting the other half of the horizontal component from the flux emitted into the upper hemisphere.

The ratio of the horizontal flux component and the total flux leaving the luminaire is called the "Horizontal

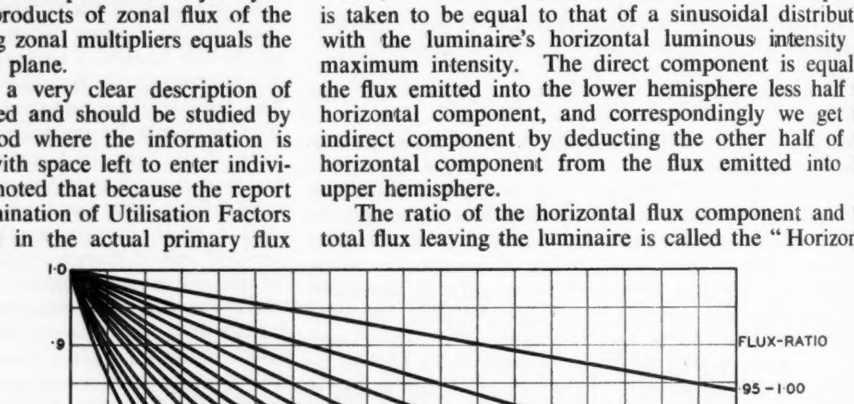

Fig. 2. Croft's surface distribution factors (simplified diagram).

Light Output Ratio" of the luminaire; similarly, the other two component ratios are the Direct and the Indirect Light Output Ratios.

The sum of these three ratios always adds up to the "Total Light Output Ratio" of the luminaire, a concept which is probably better known under its old name: "Luminaire Efficiency."

For those who have not got the polar distribution curve of the luminaire they are intending to use in an installation, Croft includes in his paper ([21]) a large table giving the component light output ratios for almost every type of incandescent and fluorescent luminaire normally encountered. When using this table it should be realised that the component light output ratios for any one type of luminaire are based on a given overall luminaire efficiency. If the luminaire one is going to use fits the description of any particular type but has a different overall efficiency the three component light output ratios have to be adjusted proportionally to add up to the luminaire's actual overall efficiency.

The next step in Croft's method is to determine what he calls the "Surface Distribution Factors." Such a Surface Distribution Factor is equal to the ratio of the luminous flux reaching a specified surface, e.g., floor, ceiling, directly from the luminaires and the total flux emitted by the luminaires.

Surface Distribution Factors depend on the polar distribution curve of the luminaires and their spacing and mounting within the room. As far as the polar distribution is concerned, Croft distinguishes between 14 different types of direct flux distribution ranging from that of a focused spotlight to that of a very broad direct luminaire, a cosine distribution for the indirect component and a sine distribution for the horizontal flux component. Which of the 14 different types of direct distribution has to be used is determined by a concept called "Flux Ratio FR."

FR is given by the following formula:—

$$FR = \frac{F_{40} - .64\ I_{90}}{F_d} \qquad \text{.................(11)}$$

where F_{40} = luminous flux of luminaire between 0 deg. and 40 deg. to the downward vertical,

I_{90} = the horizontal luminous intensity of the luminaire,

F_d = the direct flux component as defined above.

Croft considers three spacing to mounting ratios 0.5, 1.0 and 2.0, for the horizontal component and 0.5 and 1.0 for the direct component. Higher spacing ratios were not taken into account since even in cases where they occur the spacing ratio based on luminaire and wall will be of the order of 0.5, and it is this latter spacing which really matters. For the indirect component Croft has worked with two spacing-to-suspension ratios, namely 1.0 and 2.0

The curves he publishes giving the relationship between "Surface Distribution Factors," "Surface Coefficients" (see below) and the various distribution curves for selected spacing ratios clearly show that the influence of the spacing ratio is negligible as far as the horizontal flux component is concerned. It is comparatively small for the indirect component and is important only for the direct component, particularly when FR is greater than 0.50, i.e. with fittings having a distribution which is narrower than the cosine distribution.

Fig. 2 shows Croft's "Surface Distribution Factors" for a spacing ratio of 1.0; this is a simplified version of the one published by Croft in ([10]) and ([21]).

Since spacing ratios of 1.0 or at least between 0.75 and 1.25 are very common the diagram shown here should apply to many lighting installations and it is suggested that it be used as a first approximation to Croft's more complex presentation.

Reference has not yet been made to the "Surface Coefficient" used as abscissa in Fig. 2. "Surface Coefficient" is defined as the ratio of the perpendicular distance between the plane of the luminaires and the reference surface, e.g. floor, ceiling or working plane and the mean harmonic dimension of the room which in turn is given by

$$\frac{2WL}{W + L}$$

where W = width and L = length of room. Thus "Surface Coefficient" is a concept very similar to that used by Hisano([7]) to arrive at the equivalent square room (see Equation 1).

With these data at hand we can calculate the amounts of luminous flux reaching the ceiling and the floor respectively. We arrive at the flux reaching the walls by finding out what is left over after deducting the sum of floor and ceiling flux from the total flux leaving all luminaires. Thus we get the whole primary flux distribution required to use the interreflection formula (7), the luminance formulae (8a) (8b) and (8c) and Equation (10) for the Coefficient-of-Utilisation.

Practical Example

The following example has been prepared to explain better than descriptive sentences can do how to use interreflection as a means of finding the gross luminance pattern of an artificially lit room and calculating the Coefficient-of-Utilisation.

(*a*) *General Information on Room and Luminaires.*

The room to be lit is a classroom or drawing office which requires an average horizontal illumination on the working plane of about 30 lm/ft^2.

The dimensions of the room are:—

Length L = 30 ft.
Width W = 20 ft.
Height H = 15 ft.

The reflection factors of the main surfaces are:—

Ceiling R_c = 70 per cent.
Walls R_w = 50 „ „
Floor R_f = 15 „ „

As luminaire, a fluorescent semi-direct unit, using four 4 ft. 40-watt fluorescent lamps has been selected. Its polar distribution (i.e., the average distribution obtained from readings taken at right angles and parallel to axes of the lamps) and its zonal flux diagram are shown in Fig. 3. The total lamp flux in one luminaire is F=8,415 lm., the luminaire flux F_l =6,182 lm. and consequently luminaire efficiency (or total light output ratio) g=0.735. From Fig. 3 the following additional data can be obtained:

Upper hemispherical flux: F_u =2,265 lm.
Lower hemispherical flux: F_l = 3,917 lm.
Horizontal intensity: I_h = 150 cd.
Flux between 0 and 40 deg.: F_{40}=1,572 lm.
Following Croft's method we get:—

(a) Horizontal Flux Component

$$F_h = \pi^2 \times I_h = \pi^2 \times 150 = 1{,}480 \text{ lm.}$$

(b) Direct Flux Component

$$F_d = F_l - \tfrac{1}{2}F_h = 3{,}917 - 740 = 3{,}177 \text{ lm.}$$

(c) Indirect Flux Component

$$F_i = F_u - \tfrac{1}{2}F_h = 2{,}265 - 740 = 1{,}525 \text{ lm.}$$

This leads us to the three components of total luminaire efficiency, the three light output ratios:—

(d) Horizontal light output ratio: $g_h = \dfrac{F_h}{F} = \dfrac{1{,}480}{8{,}415} = 0.176$

(e) Direct light output ratio: $g_d = \dfrac{F_d}{F} = \dfrac{3{,}177}{8{,}415} = 0.377$

(f) Indirect light output ratio: $g_i = \dfrac{F_i}{F} = \dfrac{1{,}525}{8{,}415} = 0.182$

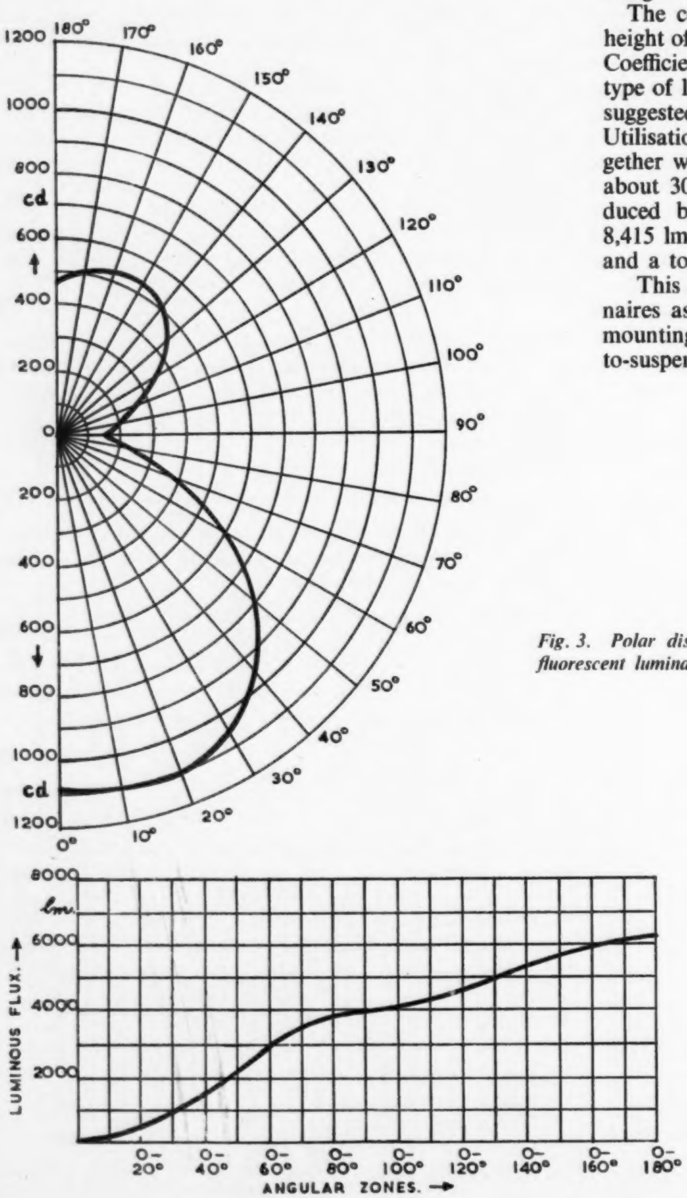

Fig. 3. Polar distribution curve and zonal flux diagram of semi-direct fluorescent luminaire.

As it should, the sum of (d), (e) and (f) adds up to the total luminaire efficiency of 0.735.

The Flux Ratio (*FR*) which indicates to which of the 14 types of direct light distribution this particular luminaire belongs follows from Equation (11) and amounts to:—

$$FR = \frac{F_{40} - 0.64\ I_h}{F_d} = \frac{1{,}572 - 0.64 \times 150}{3{,}177}$$

$$FR = 0.465.$$

This means that when using Fig. 2 (the Surface Distribution Factors) the curve labelled 0.45 – 0.50 will have to be taken.

Before we can proceed any further we have to decide the number of luminaires needed together with their mounting height and spacing ratios. The best way to approach this is to apply the standard lumen method of design as a guide.

The ceiling height being 15 ft., we select a mounting height of 10 ft. above floor, i.e., 7 ft. above working plane. Coefficient of Utilisation tables will tell us that with the type of luminaire selected, the room as described and the suggested mounting height we shall get a Coefficient of Utilisation of 0.38. Neglecting maintenance factor altogether we find that to obtain an average illumination of about 30 lm/ft² at least 47,500 lm. will have to be produced by the lamps installed. With a lamp flux of 8,415 lm. in each luminaire six luminaires will be needed and a total flux *F* of 50,490 lm. will be available.

This leads to the mounting and spacing of the luminaires as indicated in the sketch of Fig. 4. Spacing-to-mounting ratio (based on the floor) will be 1.0 and spacing-to-suspension ratio will be 2.0.

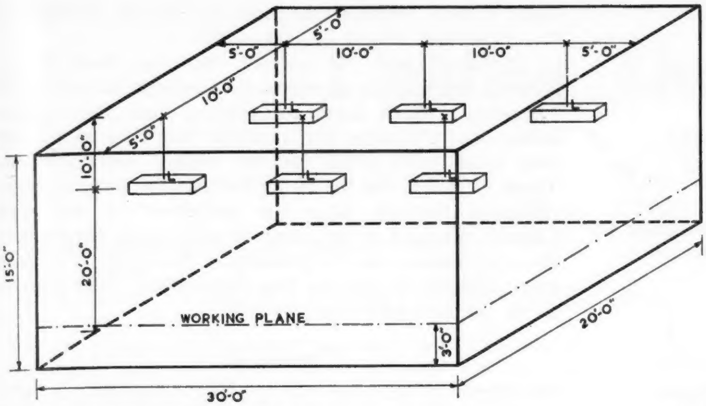

Fig. 4. Sketch of room used in the example, showing mounting and spacing of luminaires.

(*b*) *Primary Flux Distribution.*

Following the procedure proposed by Croft, we first have to determine the surface coefficients for ceiling, floor and working plane. These are:—

Ceiling surface coefficient $k_c = \dfrac{h_c\,(W + L)}{2WL}$,

Floor surface coefficient $k_f = \dfrac{h_f\,(W + L)}{2WL}$,

Working plane surface coefficient $k_{wp} = \dfrac{h_{wp}\,(W + L)}{2WL}$,

where h_c = perpendicular distance between ceiling and luminaire = 5 ft.,
h_f = perpendicular distance between floor and luminaire = 10 ft., and
h_{wp} = perpendicular distance between working plane and luminaire = 7 ft.

With W = 20 ft. and L = 30 ft. we get:—

$k_c = .208$; $k_f = .416$ and $k_{wp} = .292$.

In the second stage we use the diagram shown in Fig. 2 to obtain the various surface distribution factors.

CEILING:—

(a) Indirect light output ratio based on cosine distribution (i.e. curve for $FR = .40 - .45$): for $k_c = .208$ we get a Surface Distribution Factor D_{ci} of .705.

(b) Horizontal light output ratio based on sine distribution (curve marked "horizontal"): for $k_c = .208$ we get $D_{ch} = .208$.

(c) No direct light output ratio.

FLOOR:—

(a) No indirect light output ratio.

(b) Horizontal light output ratio using curve marked "horizontal":—
for $k_f = .416$ we get $D_{fh} = .112$.

(c) Direct light output ratio, using curve with $FR = 0.45 - 0.50$.
for $k_f = .416$ we get $D_{fd} = .560$.

WORKING PLANE:—

(a) No indirect light output ratio.

(b) Horizontal light output ratio, using curve marked "horizontal":—
for $k_{wp} = .292$ we get $D_{wph} = .160$.

(c) Direct light output ratio, based on curve with $FR = 0.45 - 0.50$:—
for $k_{wp} = .292$ we get $D_{wpd} = .660$.

These various surface distribution factors D enable us to calculate the light output ratios for ceiling, floor and working plane. These ratios will tell us how much of the lamp flux reaches the various surfaces directly from the luminaires. Thus this is the last step before arriving at the primary flux distribution.

CEILING: The light output ratio of the ceiling is:—

$$g_c = g_i \times D_{ci} + g_h \times D_{ch}$$
$$\therefore\ g_c = .182 \times .705 + .176 \times .208 = .165.$$

FLOOR: The light output ratio of the floor is:—

$$g_f = g_d \times D_{fd} + g_h \times D_{fh}$$
$$\therefore\ g_f = .377 \times .560 + .176 \times .112 = .231.$$

WORKING PLANE: The light output ratio of the working plane is:—

$$g_{wp} = g_d \times D_{wpd} + g_h \times D_{wph}$$
$$\therefore\ g_{wp} = .377 \times .660 + .176 \times .160 = .277.$$

The *flux reaching the ceiling* directly from all six luminaires is now given by:—

$$F_c = F \times g_c = 6 \times 8{,}415 \times .165.$$
$$F_c = 8{,}340 \text{ lm.}$$

Similarly, we get the *flux reaching the floor* directly from the luminaires:—

$$F_f = F \times g_f = 6 \times 8{,}415 \times .231.$$
$$F_f = 11{,}680 \text{ lm.}$$

and the *flux reaching the working plane*:—

$$F_{wp} = F \times g_{wp} = 6 \times 8{,}415 \times .277$$
$$F_{wp} = 14{,}000 \text{ lm.}$$

The *flux reaching the four walls* is obtained by subtracting the sum of ceiling flux and floor flux from the total luminaire flux F_l.

Since $F_l = 6 \times 6{,}182 = 37{,}100$ lm.

we get: $F_w = 37{,}100 - (8{,}340 + 11{,}680) = 17{,}080$ lm.

Thus the required primary flux distribution is characterised by the following three component fluxes:—

$$F_c = 8{,}340 \text{ lm.}$$
$$F_w = 17{,}080 \text{ lm.}$$
$$F_f = 11{,}680 \text{ lm.}$$

F_{wp} is not required for the subsequent calculation of the interreflected illumination but is needed to arrive at the Coefficient of Utilisation of the installation (see section (d) below).

(*c*) *Interreflection and Luminances of Ceiling, Walls and Floor.*

The illumination becoming available by interreflection E_r is calculated by using Equation (7):—

$$E_r = \frac{F_c R_c + F_w R_w + F_f R_f}{A_c\,(1 - R_c) + A_w\,(1 - R_w) + A_f\,(1 - R_f)}$$

and with $A_c = 600$ sq. ft.,
$A_w = 1500$ sq. ft., and
$A_f = 600$ sq. ft.

we get:—

$$E_r = \frac{8{,}340 \times .70 + 17{,}080 \times .5 + 11{,}680 \times .15}{600 \times .30 + 1{,}500 \times .5 + 600 \times .85}$$

$$\therefore E_r = 11.2 \text{ lm/ft}^2.$$

The average luminances of ceiling, walls and floor are obtained by using Equations (8a), (8b) and (8c).

We have:—

$$\text{Ceiling luminance } L_c = R_c\left(\frac{F_c}{A_c} + E_r\right)$$

$$\therefore L_c = 0.7\left(\frac{8{,}340}{600} + 11.2\right) = 17.5 \text{ ft.-L.}$$

$$\text{Similarly, wall luminance: } L_w = R_w\left(\frac{F_w}{A_w} + E_r\right)$$

$$\therefore L_w = 0.5\left(\frac{17{,}080}{1{,}500} + 11.2\right) = 11.3 \text{ ft.-L.;}$$

and finally: floor luminance:—

$$L_f = R_f\left(\frac{F_f}{A_f} + E_r\right)$$

$$\therefore L_f = 0.15\left(\frac{11{,}680}{600} + 11.2\right) = 4.6 \text{ ft.-L.}$$

(d) Total Average Illumination on Working Plane and Coefficient-of-Utilisation.

The total average illumination on the working plane will be:—

$$E = \frac{F_{wp}}{A_{wp}} + E_r$$

$$\therefore E = \frac{14{,}000}{600} + 11.2 = 34.6 \text{ lm/ft}^2.$$

The Coefficient-of-Utilisation becomes:—

$$\text{C-of-U} = \frac{E \times A_{wp}}{F} = \frac{34.6 \times 600}{50{,}490}$$

$$\text{C-of-U} = 0.41.$$

This value is only slightly higher than the C-of-U used in the preliminary investigation but is in excellent agreement with the value we obtain if we use the method of calculating the C-of-U explained in the American IES Report[20].

Concluding Remarks

It is hoped that by explaining the foregoing practical example in such detail it will have been possible to convince the reader that Croft's method of calculating the primary flux distribution and the subsequent application of a simple formula for the amount of illumination created by interreflection is by no means beyond the resources of the ordinary lighting engineer. Whether the method is used to get an idea of the gross luminance pattern or to determine coefficients-of-utilisation does not matter, it serves both purposes simultaneously.

It remains to be stressed once more that the method as described in this article employs certain simplifications and one should be aware of these. This refers particularly to installations using luminaires with a high flux ratio and spacing ratios very different from 1.0. In such cases Croft's original diagram of surface distribution factors should always be consulted.

It should also be realised that the interreflection formula used here is a compromise between accuracy and simplicity. Much more complicated methods of calculating interreflections are available but only rarely will they reveal more detail than the method described here. There is little sense in asking for a more accurate interreflection formula since the usefulness of any such formula is linked to the accuracy with which the primary flux distribution can be predicted. Normally it is much more difficult to get the flux distribution right than to tackle the interreflection correctly.

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Lighting Abstracts

OPTICS AND PHOTOMETRY

612.843.367

474. Discomfort glare at low adaptation levels. II—Off-axis sources.

R. C. PUTNAM and W. F. GILLMORE, Jr., *Illum. Engng.*, **52,** 226-229 (*Apr.*, 1957).

An experimental technique previously used to study discomfort glare at luminance levels and source sizes corresponding to street lighting conditions has been extended to investigate the effect on discomfort of the position of a glare source relative to the direction of viewing. Observations from 10 observers enabled relationships to be derived showing the increase in source luminance necessary to produce the given glare criterion (BCD) as the angular position of the source was increased. P. P.

475. Assessment of brightness: What we see. 612.843.36

R. G. HOPKINSON, *Illum. Engng.*, **52,** 211-222 (*Apr.*, 1957).

In order that the physical constants of a lighting installation can be interpreted in terms of "What we see," a scale of subjective brightness is required. Laboratory determinations of such a scale by contrast scaling, by means of a luminosity photometer and by a method of direct estimation are described. Results obtained from the latter method were used to give relationships between brightness magnitude (estimated on a free-choice numerical scale) and source luminance for various adaptation levels. The use of the apparent brightness scale is demonstrated for room interiors lighted by daylight and by artificial light. P. P.

612.843.31

476. Apparent intensities of coloured signal lights.

W. E. K. MIDDLETON and H. S. T. GOTTFRIED, *Illum. Engng.*, **52,** 192-196 (*Apr.*, 1957).

An experiment has been conducted to determine whether a reliable guide to the apparent brightness of a coloured signal light can be obtained by calculating its luminous intensity from spectral energy distribution data. The experiment showed that red signals appeared much more intense and blue signals much less intense than was indicated by the calculations. No conclusions could be drawn, however, as to whether this arose from a breakdown in Abney's additivity law or to the C.I.E. photopic luminosity function being inapplicable to a point source. P. P.

LAMPS AND FITTINGS

621.327.534.15

477. Operating parameters of high output fluorescent lamps.

W. C. GUNGLE, J. F. WAYMOUTH and H. H. HOMER, *Illum. Engng.*, **52,** 262-267 (*May*, 1957).

Very high output (VHO) fluorescent lamps have been developed producing between two and four times the light output of conventional lamps of the same dimensions. This has been made possible by maintaining a limited area of the bulb wall near the optimum operating temperature for the mercury vapour and by using neon rather than argon or krypton for the filling gas. Details are given of the operating characteristics of the lamps, particularly with varying ambient temperature, and of the construction of the "cool" end to the bulb. Stabilisation of light output takes much longer with this type of lamp. P. P.

621.327.534.2

478. Phosphors for high pressure mercury lamps.

M. J. B. THOMAS, K. H. BUTLER and J. M. HARRIS, *Illum. Engng.*, **52,** 279-285 (*May*, 1957).

Improvements in the colour rendering of high pressure mercury vapour lamps have been achieved by coating the outer bulb wall with an appropriate phosphor. The special requirements for this phosphor are compared with those for low pressure fluorescent lamps, and their realisation in terms of sulphide, manganese activated and orthophosphate phosphors are described. With the latter type of phosphor, increased light output as well as improved colour rendering are obtained. Further developments are blue, green, yellow and red lamps. P. P.

621.327.534.15

479. Factors to be considered in the design of high output fluorescent lamps.

J. F. WAYMOUTH, F. BITTER and E. F. LOWRY, *Illum. Engng.*, **52,** 257-261 (*May*, 1957).

Increasing levels of artificial lighting have resulted in the need for fluorescent lamps of higher light output. If this is sought by increasing the power input to fluorescent lamps of conventional size, a "cool" end to the lamp bulb has to be provided to maintain the mercury vapour pressure at an optimum. Even then the production of ultra-violet radiation is influenced by the filling gas, neon being more effective than either argon or krypton at these higher power inputs. P. P.

480. The starting of fluorescent lamps. 621.327.534.15

D. T. WAIGH and L. C. WILTSHIRE, *Trans. Illum. Eng. Soc.* (*London*), **22,** 115-131 (*No.* 5, 1957).

Discusses methods of starting hot-cathode fluorescent lamps under three categories which cover most common starting devices. Data are given which show how starting is effected by lamp parameters and conditions external to the lamp. The choice of starting methods is briefly discussed with reference to the limitations of the more common types. W. R.

LIGHTING

481. Colour recognition and dazzle signal lights. 628.975

W. ARNDT and E. A. VOIT, *Lichttechnik*, **9,** 186-190 (*April*, 1957). *In German.*

An extended series of laboratory tests has been made for the German Ministry of Transport to determine the lower limits at which the colours of white, red, yellow, green and blue signals can be recognised and the upper limits at which glare becomes objectionable, for different values of uniform surround luminance ranging from 0.01 to 100 ft-L. The extent of the glare experienced with any particular signal was assessed by the distance sideways from

the signal at which it was possible to detect a disc about 6 minutes in diameter and three times as bright as its background. The diameter of the signal light itself was about one quarter of this. The results are given in a series of graphs, the strength of a signal being expressed in terms of the illumination it produces at the eye of the observer 30 ft. away. J. W. T. W.

628.935

482. Reduction in indoor illumination with lapse of time.

E. WITTIG, *Lichttechnik*, **9**, 183-186 (*April*, 1957). *In German.*

This is a report by a committee of the German Lighting Society on "Methods of calculating illumination." After much consideration the committee has adopted the word *Verminderungsfaktor* (abbrev. v) as the nearest German equivalent of *maintenance factor*. The seven causes contributing to v are analysed in some detail and a number of tests have been made in different types of interiors. The value of v for 12 months is found to range from 0.85 with direct lighting by filament lamps to 0.3 for indirect lighting with fluorescent lamps. It is also found that if v_n is the value of v after n months, $v_6 = 0.33 + 0.67v_{12}$ and $v_{12} = 0.65 + 0.35v$. J. W. T. W.

483. 450 foot-candles light an office. 628.972

BERLON C. COOPER, *Electrical Construction and Maintenance*, **56**, 76-79 (*Feb.*, 1957).

Describes a fluorescent office lighting installation at Nela Park, Cleveland, U.S.A., giving a maximum of 450 lm/ft^2. It is claimed that this installation demonstrates the possibility of providing artificial lighting of daylight standard both as regards illumination and comfort. It was noted that the occupants regularly operated the system at full light output although the illumination level was under their full control. W. R.

484. Lighting in the hospital. 628.97

Lux, **25**, 12-21 (*Jan.-Mar.*, 1957). *In French.*

Describes and illustrates a number of different systems for the lighting of hospital operating theatres and hospital wards. J. M. W.

628.97

485. A method of evaluating seeing distances on a curved road and its application to headlight beams in current use.

V. J. JEHU, *Trans. Illum. Eng. Soc.* (*London*), **22**, 69-83 (*No.* 3, 1957).

A method is described by which direct seeing distances can be evaluated where two vehicles meet on a curved road at night. It is shown that, in some circumstances, the modern British system is better than the symmetrical European system, and that in others the order is reversed. The modern British system is almost always better than the European in revealing the important nearside object, and seeing for all object positions is considerably better during the early stages of a meeting on a curved road, when the observer is on the inside of the bend. These conditions closely resemble those of open road driving with meeting beams, a frequent occurrence on busy roads. Since the British system is stated to be also less susceptible to vertical mis-aim it is concluded that it is better suited to actual road conditions. A comparison is made between the modern double lamp British system and the previous single-lamp system. W. R.

628.93

486. A method of calculating flux from an isocandle diagram using a system of discrete points.

DOREEN SMITH, *Trans. Illum. Eng. Soc.* (*London*), **22**, 105-115 (*No.* 4, 1957).

Describes a method of calculating the light flux represented by the whole or part of an isocandle diagram by reading the intensity of a number of points in a carefully chosen array and applying a simple formula. Two types are described, one suited to the calculation of the total light output of a lantern, the other for the production of utilisation factor curves for roads of varying width with various lantern mounting arrangements. W. R.

628.971

487. Mercury floodlighting—Its advantages and limitations.

J. R. BALE, *Illum. Engng.*, **52**, 235-242 (*Apr.*, 1957).

The use of clear bulb and fluorescent mercury lamps for floodlighting purposes is considered in respect of beam spread, candlepower and efficiency, stroboscopic effect, power failure, colour rendering and operating costs. Fluorescent mercury lamps are only suitable for short distance floodlighting of broad areas. Clear bulb lamps can be used with existing reflectors and give practically any desired beam spread. The economic advantages of mercury over filament lamps depend very much on type of use (general floodlighting or sports fields), electricity charges, burning hours and operating voltage in relation to rated lamp voltage. P. P.

488. Algebraic interflectance computations. 628.93

J. R. JONES and J. J. NEIDHART, *Illum. Engng.*, **52**, 199-205 (*Apr.*, 1957).

The light flux from a luminaire is followed through its successive reflections between the surfaces of a room and the fraction passing through the working plane on each occasion is added algebraically to give formulae whereby the interreflected light (actually the "interflectance values") in the room can be computed. Comparisons are made with corresponding values given by the methods of calculation developed by Moon and Spencer and by Dourgnon and Cadiergues. Checks were also made against the measured data of Potter and Russell. The development of the formulae is described in an appendix. P. P.

628.97

489. Lighting installations in the new sports hall at Boras.

L. HJORT, *Ljuskultur*, **29**, 32-34 (*No.* 2. *Apr.-June*, 1957). *In Swedish.*

The new building comprises four sports halls, a restaurant and entrance hall, with auxiliary rooms. The main tournament hall has built-in rows of fluorescent lamps for the general illumination, with ceiling projectors for spotlighting the central portion of the hall. The smaller halls rely entirely on fluorescent lighting. R. G. H.

628.971

490. EFAS—A new and vital aid to low visibility landings by aircraft.

D. I. COGGINS, *Illum. Engng.*, **52**, 289-294 (*May*, 1957).

A new system of airfield approach lighting (the Electronic Flash Approach System or EFAS) has been developed for low visibility landings, the principal feature being a line of condenser discharge flash units along the centre of the glide path extending to 3,000 ft. from the runway threshold. The units operate on a $\frac{1}{2}$-second cycle and produce the effect of "a white hot ball streaking towards the runway at 3,600 m.p.h." It is claimed that the flashes do not cause blinding or loss of adaptation to the pilot. In addition they need not be dimmed to prevent fog glare during low visibility approaches. P. P.

Illuminated Borders to Picture Screens

By J. J. Balder*

A series of tests was carried out in which a person looking at a picture screen was asked to give his opinion as to the ideal luminance and width of a uniformly illuminated border round the picture for ensuring optimum viewing comfort. The observations were made by 20-25 persons for a number of luminance levels of both screen and surroundings.

It is now generally agreed that with the high picture luminance levels of modern cathode ray tubes, TV viewing is more pleasant if there is some measure of illumination in the room where the viewers are seated ; in other words, it is desirable to have a certain luminance level round the picture. This surround luminance will generally be relatively low. The sudden change between screen luminance and surround luminance can be avoided by introducing a transitional luminance as a direct border to the picture area. The light-coloured border enclosing the screen on the majority of sets already serves this purpose. A possible further contribution to viewing comfort would be to fit a border illuminated to a desired luminance level. The desirable width and luminance of such a border were ascertained by observations carried out by a number of people.

The application of the results of the tests to cinema screens is also discussed.

(1) Description of the experiment

In the absence of suitable TV transmissions at the right times, a black-and-white film was projected from a 16-mm projector on to a screen measuring 480 x 360 mm to simulate a TV screen. By using a light blue filter the colour of the projected picture was made equal to that of a TV screen. The projection screen was framed by a border (Fig. 1) the width and luminance of which could be adjusted by knobs operated by an observer seated 2.2 metres away from the screen. The surroundings, made up of grey or black curtain and paper, had a uniform luminance throughout the entire field of vision. Films were projected that showed no substantial "macroscopic" luminance differences over the different parts of the screen (in order that the term "average screen luminance" would make sense). For the adjustment of the desired luminance and width of the border periods of one or several minutes were used during which the average screen luminance had a virtually constant value (±10 per cent.) The contrasts of the projected films were normal.

The experimental procedure was for the observer to look (and listen) to the film at a particular level of surround luminance. So that his interest in the film would not flag, it was always ensured that he had not previously seen it. Whilst he was looking at the film he was asked

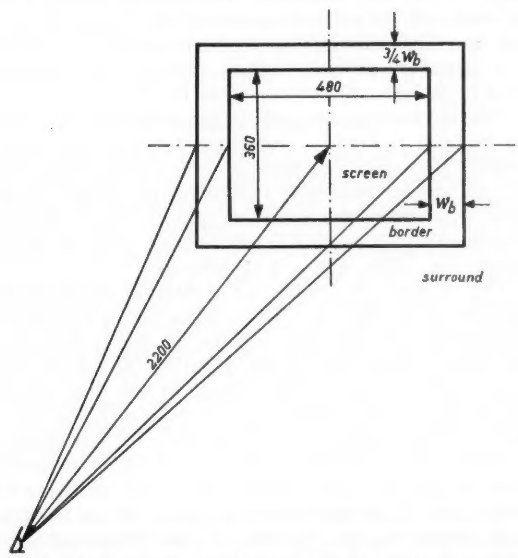

Fig. 1. Sketch of the viewing situation (Dimensions in mm.)

at various times (when the luminance levels of the screen were suitable) to adjust the border :—

(a) to the preferred luminance at each of four given widths of the border ;

(b) to the preferred width at each of four given luminance values of the border.

It is stressed that the observer was instructed to effect

Table 1

List of the screen and surround luminances at which observers were asked to adjust the width and luminance of the border.

$B_{surround}$ (cd/m²)	0.005			0.5			5.0	
average B_{screen} (cd/m²)	2.0	7.3	30	3.8	9.1	32	25	48

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the adjustments whilst looking at the film. This is not easy, but it is important in this way to try to not pay greater attention to the border than would be the case in reality. The instruction given to the observer was to select the most comfortable "viewing condition."

For each of a number of combinations of screen and surround luminance, given in Table I, 20 to 25 observers individually adjusted the width and luminance of the border in the manner described.

The width of the border (designated by w_b in Fig. 1) could be altered from 0 to 160 mm. and its luminance adjusted between 0 and 34 cd/m^2.

(2) Apparatus

Fig. 2 shows the set up of the apparatus from the observer's side, *P* being the film projector. A pale-blue filter fitted in front of the objective lens helps to ensure the projected picture being of the same colour as a TV screen. From where the observer sits, the luminance of the border *B* round screen *S* can be set by knob k_1 and its width by the controls k_2 (one of which is the control for reversing the direction of movement). The person in charge of the test measures the adjusted border-widths and reads off the set luminances of the border from the scale *Sc*. The necessary surround luminance is obtained by a variable, general, diffuse lighting; the reflection factor of the general surround can be altered.

The mechanism for setting the width of the border may be seen in Fig. 3. This illustrates how the position of two "K-shaped" diaphragm-parts *D* which are opposite one another and slide symmetrically in their sloping frame determines the width of the border. A motor (controlled by k_2 in Fig. 2) moves both parts of the diaphragm via cables and a transmission.

The manner in which the border is illuminated is apparent from Fig. 4. Two colour-corrected mercury lamps housed in the case *L* shine on to the rear of the opal plastic sheet, part of which forms the border round the projection screen. The colour of the light matches that of the picture. Fig. 5 is a close-up of the case *L*. Both iris diaphragms *d* which regulate the luminance of the border are controlled by knob k_1 of Fig. 2 via cable *c*. With the aid of a gear-wheel, this cable moves a rack to which the diaphragm arms are fixed. *M* is a 'magslip' which transmits the position of the diaphragms (and hence the value of the luminance of the border) via a second 'magslip' to the scale *Sc* (Fig. 2) near the person in charge of the test.

(3) Results

The results of the adjustments carried out by an observer can be plotted for each selected luminance level of screen and surroundings in the manner illustrated by the example in Fig. 6. When a line *a* is drawn as near as possible through the points (circles) representing the adjustments of the luminance for four widths of the border, and a line *b* drawn through the points (crosses) representing the preferred width of the border for four different values of its luminance, then the point *Q* at which the lines *a* and *b* intersect indicates the combination of co-ordinates the observer favours.

A cluster of such points *Q*, representing the preferences of all observers, can be plotted for each luminance level of screen and border. The divergence in individual preferences is then shown to be considerable. These "scatter diagrams" are not reproduced here, but the

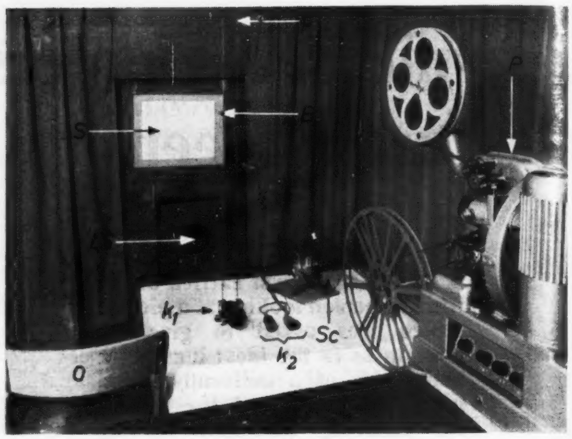

Fig. 2. General view of the test arrangement. (P = projector, S = screen, B = border, O = observer's chair, LS = loudspeaker, k_1 = knob controlling border luminance via cable c, k_2 = controls for adjustment of the border width, Sc = scale showing border luminance.)

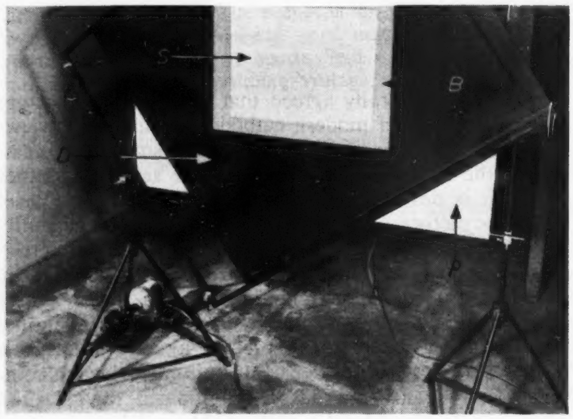

Fig. 3. Mechanism for adjusting the width of the border. (S = projection screen, B = border forming part of the sheet of opal plastic p, D = two movable diaphragms.)

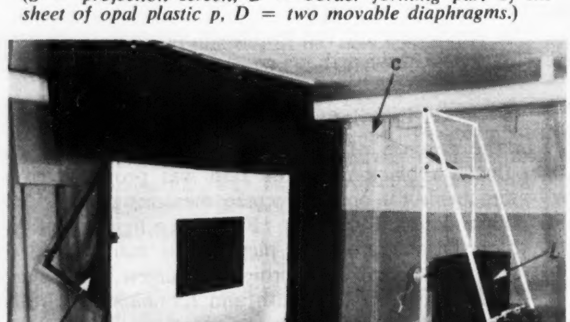

Fig. 4. Arrangement at rear of screen. The opaque black rear of the screen is seen against the white opal plastic p of which the border round the screen is part. Two HPL lamps in the case L provide the light for the border luminance. The amount of light emitted (and thus the luminance of the border) is regulated by means of iris diaphragms that are controlled by knob k_1 (see Fig. 2) via cable c.

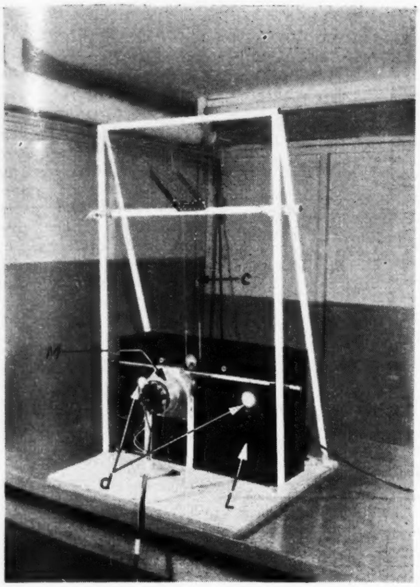

Fig. 5. Detail of case L which provides the border luminance from behind the screen. (d = iris diaphragms, c = cable by which the aperture of the diaphragms can be modified. The 'magslip' M transmits the position of the iris diaphragms to the scale S_L (Fig. 2).

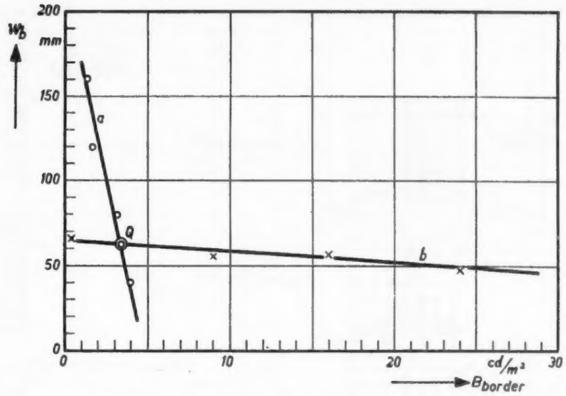

Fig. 6. Graph of the two sets of four adjustments carried out by each observer for every given level of screen and surround luminance; four adjustments of luminance at given border widths (connected by line a); four border-width adjustments at given border luminances (connected by line b). The point Q at which a and b intersect gives a combination of the two co-ordinates favoured by this observer.

results of the test-observations are arranged in two separate series of frequency distributions, one showing the percentages of the observations in which the various widths of the border were preferred, the other showing the percentages of the observations in which the various values of the border luminance were favoured (Figs. 7a and 7b respectively).

(3.1) *The width of the border*

It is apparent from Fig. 7a that, in each case, preference regarding the width of the border differs widely. The averages of these values are not systematically dependent upon the luminance of either screen or background (see Fig. 8a). There is justification for determining an average frequency-distribution of the border-width preference for all luminance values of screen and surroundings (Fig. 8b). The mechanism of the adjustment was such that the adjustments could not be influenced by the limitations of the variation range. On the average, the preferred border width is W_b = 72 mm, or, expressed in more general terms, 0.3 × half the dimension of the picture. This corresponds to an angular single border-width, measured in a horizontal plane, of 1.8 deg. with a horizontal picture dimension of 12 deg.

(3.2) *The luminance of the border*

Fig. 7b shows, for all cases of screen and surround luminance, the percentages of the observations in which the border luminance is preferred to be within the indicated luminance ranges. Here, too, there are wide divergences in the individual preferences. Nevertheless a clear trend is evident in the various average values (despite the "abnormality" of the distributions, we can still use averages; the median values are only slightly different). In Fig. 9 are shown the average values of the preferred border luminances for three surround luminances as a function of the average screen luminance.

(4) Discussion of the results

The result referred to in para. (3.1) above is sufficiently clear: tastes differ as to the desired border-widths but the average preference is a width of 0.3 × half the dimension of the screen. This result is deliberately expressed in such general terms since there is actually scant reason for assuming that it would not also apply to projection screens in theatres, etc., where everything is proportionally larger. For TV sets, the size quoted for the border is a quite acceptable one, differing hardly from that of the picture frames currently in use on modern TV receivers.

The preferred value for the luminance of the border when viewing television or cinema film projection is discussed below.

(4.1) *Television*

The luminance values of the lightest areas in the picture of a modern TV set, during an average programme, with the brightness and contrast controls normally adjusted, will in most cases lie between 70 and 200 cd/m^2. The luminances averaged over the whole screen, however, normally show values between about 10 and 50 cd/m^2 and mostly between about 15 and 35 cd/m^2. The surround luminances in lighted rooms where a TV programme is being watched will range from about 1 to 5 cd/m^2. From Fig. 9 it appears that in these circumstances, on average, a luminance of between roughly 10 and 20 cd/m^2 will be needed for the border, or, somewhat wider, between about 8 and 26 cd/m^2. To fulfil the wishes of the majority of viewers (as follows from Fig. 7b), it must be possible to increase this border luminance to approximately 35-40 cd/m^2 and reduce it to virtually 0 cd/m^2.

What effect does a conventional, non-independently lit border give? If it is rather light in colour, its luminance in certain conditions of room lighting will sometimes reach a level of 10 cd/m^2. Moreover, depending upon its slope and curvature towards the picture tube, depending also upon its reflecting properties, the border may receive a

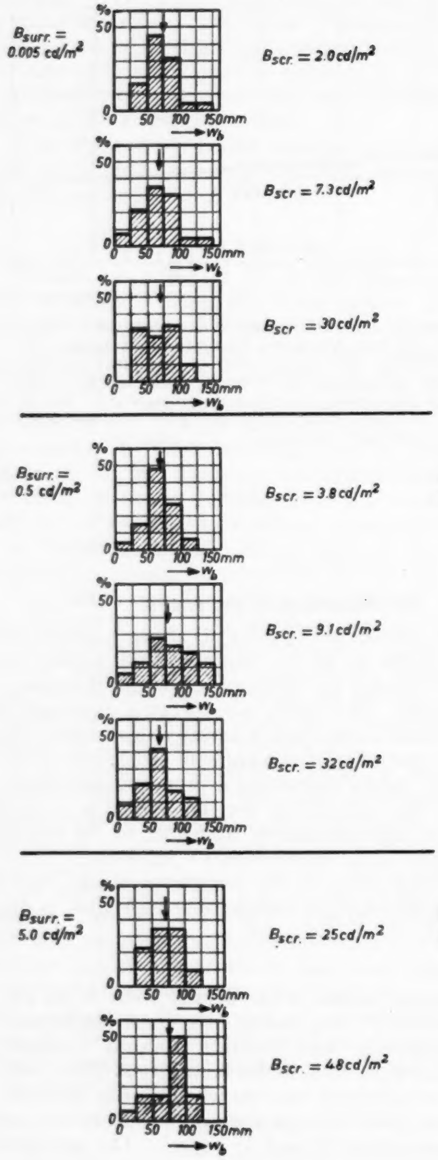

Fig. 7a (left). Frequency distribution (in percentage of observations) of the preferred border widths for the various specified values of surround and screen luminance. The averages are indicated by arrows. Total number of observers in all cases 20—25.

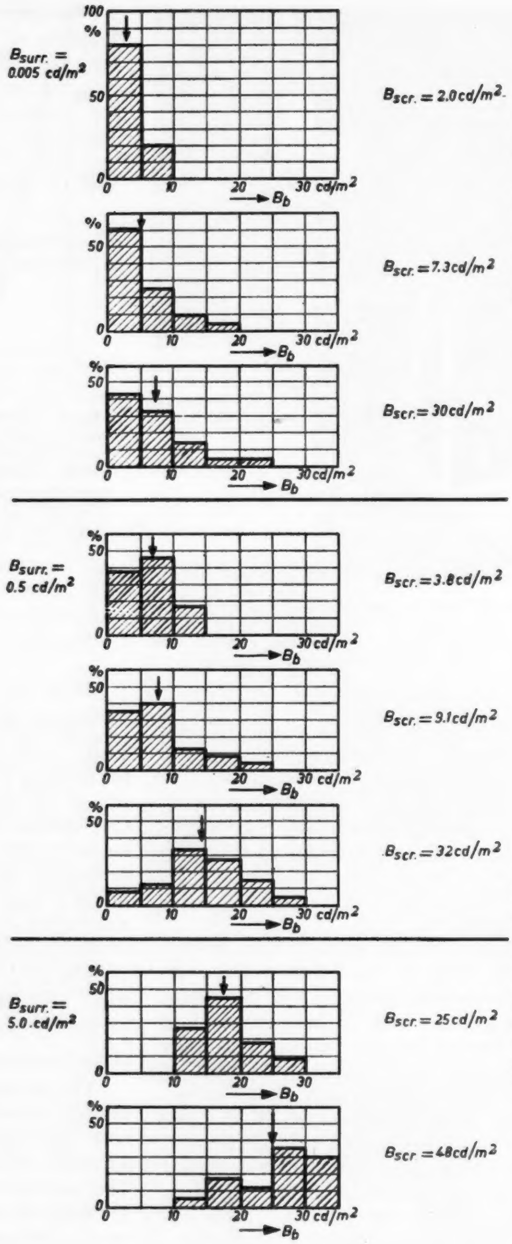

Fig. 7b (right). Frequency distribution (in percentage of observations) of the preferred border luminances for the various specified values of surround and screen luminance. The averages are indicated by arrows. Total number of observers in all cases 20—25.

luminance contribution of a few cd/m² from the picture itself, either direct or via the face plate. This contribution has the advantage of fluctuating up and down with the picture luminance, which may sometimes turn into a disadvantage, however, if direct reflections of rapid, local luminance changes are too pronounced.

Dull, fairly dark grey borders will frequenty not exceed 5 cd/m² without special treatment.

Experiments in which the border was given a colour (various colours were tried) had negative results: all observers preferred a border in the same tint as the pale-bluish television picture.

(4.2) *Cinema screens*

With the gradual replacement of the conventional sizes of cinema projection screens by CinemaScope and other kinds of "wide screen," entirely different viewing conditions have been created in cinemas. Nevertheless, for the sake of completeness, the results of the observations are applied to the case of the orthodox projection screens, the angular dimensions of which—as seen by the average film-goer—are comparable to those of the screen in the experiments.

Current luminance levels for such film projection screens, measured without film in the projector and with

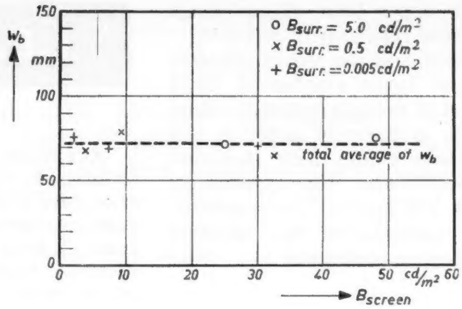

Fig. 8a (left). Average values of the desired border widths as a function of the average screen luminance for three surround luminances.

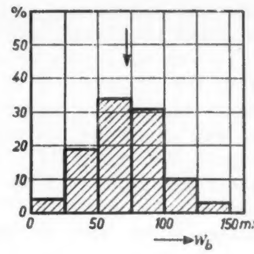

Fig. 8b (right). Averaged frequency distribution of the preferred border widths. The arrow indicates the general average (corresponding with the dotted line in Fig. 8a).

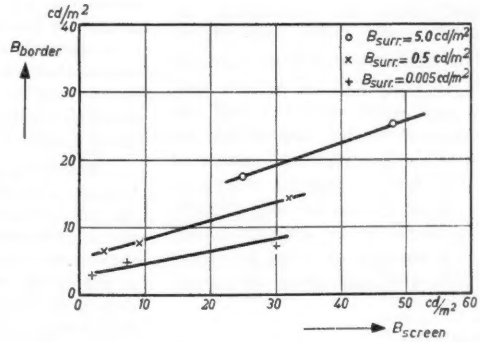

Fig. 9. Average values of the preferred border luminance as a function of the average screen luminance for three surround luminances.

rotating shutter, vary between about 20 and 80 cd/m² for the centre of the screen*. The average of the luminance measured over the whole screen during the projection of a film lies roughly between 0.01 and 0.2 of the "open" values, i.e., mostly between about 0.2 and 15 cd/m², more often between 1 and 6 cd/m². (These values are a good approximation for coloured films also. Projection on enlarged screens, of course, results in lower screen luminances, which may be corrected by the use of directional reflecting screens and/or by increasing the light output of the projector.)

The surround luminance in cinemas is usually close to the lowest value in the test. On the basis of the test results (Fig. 9), one might expect that on the average a border luminance of about 3-4 cd/m² would be preferable here: Fig. 7b gives the deviation in the preferred values.

Some observations during the projection of coloured films indicate that no essentially different conclusions as to preferred border width and luminance are to be expected in such cases.

The appearance of the picture at relatively high border luminances tends to resemble that of a mounted picture postcard. It does not seem impossible that this would have a weakening effect on the viewer's illusion of participating in the scene.

The importance of these considerations on the viewing conditions of "old-fashioned" cinema projection screens has declined owing to the scale on which wide-screen projection has been adopted.

(5) Comparison with results previously published

In 1951 Guth(1) published the results of an experiment in which five observers took part. The desired border luminances were given as a function of the average screen luminance. The border width applied in these tests is not mentioned quantitatively. The surround luminance is stated to have no influence as long as it is lower than the border luminance. The concluded desired values of the border luminances (measured up to about 20 cd/m² average screen luminance) are approximatey half as high as those found in our experiments at the lowest surround luminance.

Nixon's paper (2), 1956, gives the results of observations by six persons. In these experiments the screen had the same angular dimensions as in our tests. The preferred border luminance was adjusted by the observers at three given border widths: about 0.15 x, 0.9 x and 1.6 x half the screen dimensions. Earlier remarks of Petherbridge and Hopkinson regarding the preferable luminance distribution within the visual field were at the back of the choice of the very large borders. The fact that the surround luminance in Nixon's experiments was always about 0.1 x the border luminance was in keeping with these ideas.

The preferred border luminances found by Nixon (measured up to screen luminances of approximately 80 cd/m²) are also lower than those recorded in the tests described in this article, at least for the larger borders. (For the largest they are in reasonable agreement with Guth.) For the small border they are mostly situated between the two series of values of border luminances which were preferred in our experiments for the two lower

* These values are based on recent measurements in cinema theatres in the Netherlands. The recommendation drawn up by Committee 62d of the CIE in Stockholm in 1951, relating to the luminance at the centre of the screen is: 35^{+15}_{-10} cd/m². (At the edge of the screen, the luminance has to be at least ¾ of this figure.) The ASA standard specifies 10^{+4}_{-1} ft.-L (= 34^{+14}_{-3} cd/m²). Some 50 per cent. of the indoor theatres in the United States comes within this standard. British Standard 1404; 1953, requires for the centre of the screen, measured from any seat in the auditorium, a luminance between 8 and 16 ft.-L (27 and 55 cd/m²), which at the vertical edges of the screen shall be reduced to between 0.6 and 0.75 x its value.

surround luminances. (The upper limit of our range of screen luminances was lower than that of Nixon's.)

To sum up it may be stated that the results gathered from the observations of our larger number of 20-25 observers, giving an indication of average preferred values as well as of the deviations in personal tastes in this respect, do reasonably include within their deviation limits the results of Guth and Nixon. Our experiments give broader information on the issue of the preferable border width and on the influence of the surround luminance on the required border luminance.

Conclusion

As far as individual preferences are concerned, the borders required to frame a TV screen differ very largely in width and luminance. The border width most required on average appears to be independent of screen and surround luminance and is equivalent to 0.3 x half the screen dimension. The required border luminance, on the other hand, is a function of both screen and surround luminance. For modern TV sets in lighted rooms, a border luminance of about 10 to 20 cd/m^2 will usually be required on average. In order to be able to satisfy the wishes of the majority of viewers, it must be made variable between approximately zero and about 40 cd/m^2.

References

(1) S. K. Guth, Journ. Soc. Mot. Pict. & Tel. Eng., **57**, 214 (1951).
(2) R. D. Nixon. Trans. Illum. Eng. Soc. (London), **21**. 205 (1956).

I.E.S. ACTIVITIES

Birmingham Centre

At a recent meeting of the Birmingham Centre Mrs. Kay Hudson, Women's Feature Editor of the *Birmingham Mail*, gave a lecture on domestic lighting from the woman's point of view. Representatives of women's organisations from all parts of the Midlands were present including the Electrical Association for Women and members of the staff of the Midland Electricity Board.

Mrs. Hudson did not hesitate to say just what she thought about the subject; the importance of lighting to a female could not be over-estimated as it made women look attractive and was most important in the trend of fashion and modern woman's make up. Mrs. Hudson went on to say that as women wore their frocks and cosmetics largely under artificial lighting they should avoid choosing these personal things under daylight but should do so under artificial light.

Displaying her knowledge of electrical contracting, Mrs. Hudson then dealt with the supply points in a house, informing her audience that a recent survey indicated that the requisite number of electrical points in a house would cost some £300; this was far too much and electrical contracting ought to be much cheaper. Mrs. Hudson said that there should be porch lights which could be lit from the gate, thus preventing people from falling over hidden obstacles in the dark; there should be a light over the garage; the hall light should be switched on from the outside of the house; numbers and names of houses should be well illuminated. She was of the opinion that in general the standard of lighting in halls and stairs left very much to be desired. She criticised the convention of placing the light in a bedroom in the window, and maintained that bedroom lights should be more mobile, with wall brackets, and standard lamps. She did not think that rise and fall types of lighting were very reliable.

Mrs. Hudson mentioned the common use of colour in ceilings and walls, but informed her audience that where strong colours were used, a strong light would have to be used. Wallpapers and paints should always be chosen under electric lighting, as this would give the correct impression of how they would appear under actual use at home.

Opening the discussion Mr. G. R. Hanson commented on the fluent manner in which Mrs. Hudson had delivered a most constructive and enjoyable paper, at the same time expressing admiration of the knowledge she had displayed of the many and varied terms applicable to the electrical industry. Mrs. Hudson was then challenged by lamp experts present that she was quite wrong about the falling off in the quality of electric bulbs. In fact she was informed that lamps were far better than they had ever been. Lamps today, received far more abuse than they ever had before; they were expected to work equally well sideways, upwards, and often at the wrong voltage.

Many ladies joined in the discussion, one question being where could women get the necessary information about domestic lighting and where could the expert lighting engineer as distinct from the ordinary electrician be found to get this advice.

On the vexed question of the cost of electric points Mrs. Hudson was informed by contractors present that the more points installed the cheaper each was. Generally speaking contracting was only keeping pace with the constant rising costs in raw material.

A vote of thanks to Mrs. Hudson was proposed by Mr. Lewin and seconded by Mrs. Truman, of the Walsall Branch of the Women's Electrical Association.

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The IES has played a major part in the development of better lighting everywhere to the direct benefit of industry. The following is a list of companies and organisations who show their appreciation of the work of the IES by being Sustaining Members of the Society. There are many more firms whose businesses have prospered in no small way because of the work of the IES and who should therefore help to sustain the Society.

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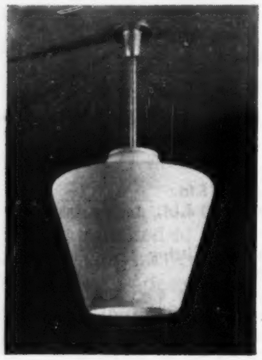
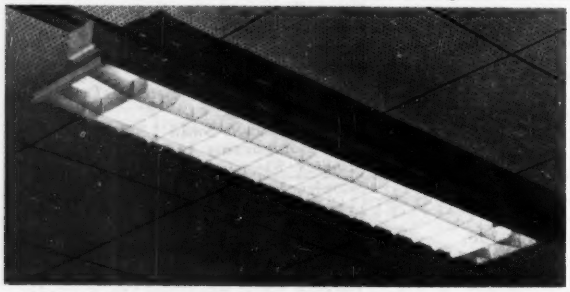
Tungsten lamp luminaire



The "Athena" fitting (Falk, Stadelmann and Co. Ltd.) is a satin opal glass unit available for ceiling or suspension fitting and in two sizes, for 150- or 200-watt tungsten lamps. Designed for general-purpose lighting, it also meets the Ministry of Education requirements for use in schools. The price of the 150 ceiling fitting is £1 9s. 4d. and that of the 200 pendant fitting is £2 1s. 8d. plus 22½ per cent. P.T. in both cases.

Louvre for closed-end fluorescent reflector

The AEI Lamp and Lighting Co., Ltd., has introduced a new white stoved enamel egg-crate louvre for use with their 5-ft. closed-end fluorescent reflector fittings. For use



with both single and twin-lamp fittings, the louvre is attached by means of four end pins which locate in the turned-up lip of the reflector. The locating pins on one side are plain and on the other, threaded. After engaging the plain pins in one side of the reflector lip, the louvre is swung up into position and secured by screwing in the threaded pins. The louvre is finished stoved enamel white. White felt is attached to the end plates to cushion the joint between reflector and louvre and the threaded pins are protected by moulded rubber sleeves to prevent damage to the reflector.

List price: £3 8s. 6d., plus P.T. (No P.T. is chargeable when sold as part of a fitting.)

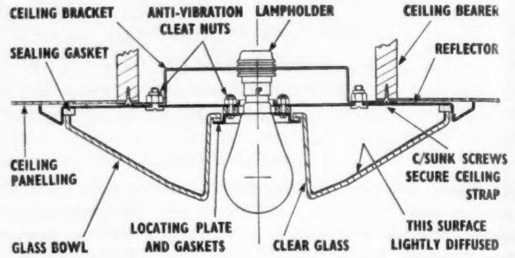
Low-voltage fluorescent unit

The Plessey Company Ltd. has introduced a self-contained fluorescent light unit to operate from low-voltage supply batteries. The DC battery supply (24 volts 0.75 amps) to the unit is converted to AC by a special vibrator working at a frequency of 200 c/s. Instantaneous starting is achieved by straightforward switching of the DC supply, thereby dispensing with the use of supplementary push-buttons or delay switching. The present unit is for 8-watt, 12-in. fluorescent lamps; units for operation on a 6- and 12-volt DC supply are under development, and it is expected that 15- and 20-watt units will be available shortly.

Tungsten lamp fitting

The "Cleanlight" fitting (AEI Lamp and Lighting Co., Ltd.) was designed in the first place for use in railway carriages where dusty conditions and changes in temperature cause dust to collect inside orthodox glass fittings. A semi-recessed version for use with 40/60-watt BS and ES pearl or silverlight lamps is now in limited production.

The fitting consists of a diffusing glass bowl semi-permanently sealed to a reflector backplate to form a totally enclosed dust-tight annular chamber around the lamp. The neck of the lamp passes through an opening in the reflector backplate into a lampholder recess behind the fitting. Dust in the air passes over the lamp and through the well to the centre of the fitting. The fitting has only four basic



parts: the lampholder bracket, the reflector backplate, the glass bowl and the bowl-locating plate. After erection only the lamp need be disturbed to clean or re-lamp the fitting.

The dimensions of the fitting are: Overall diameter 14¾ in.; depth (visible part of fitting) 3 3-16 in.; diameter of ceiling recess 7¾ in.; depth ceiling recess (maximum) 2 in.

Underwater lighting fitting

A new underwater lighting fitting is being made by E. N. Mackley and Co. to a patent of the United Kingdom Atomic Energy Authority, who already have a number of the lighting fittings in use.

Of aluminium construction, the lampholder body has a sealed side cable gland entry which gives access to the connection of the lampholder. This is secured in such a way that when the special lamp is screwed in position correct alignment is certain. This method ensures positive lamp location and contact between the neck of the lamp and its spring-loaded rubber seals. Complete water-tightness results from this system of assembly. To protect the lamp while under working conditions, an aluminium guard is fitted. The structure and water sealing arrangements will withstand water pressure at depths down to 1,500 ft. The type of lamp used is the deciding factor in the application of the fitting.

Personal

DR. F. A. BENSON has been awarded the degree of D.ENG. of the University of Sheffield.

MR. C. A. HUGHES retired on May 31 after 46 years with the Siemens Organisation. Altogether Mr. Hughes had spent 50 years in the electrical industry, having been with Falk, Stadelmann for four years before entering the service of Siemens Brothers Dynamo Works in 1911 where he was first employed as a technical assistant, dealing mainly in matters concerning tantalum lamps. He served in the Royal Engineers from 1914-18 and on returning to civil life was given the job of developing Siemens Lighting Department. In 1924 he went to the United States to study American developments in lighting. In that year he was appointed manager of the Lamp Department of Siemens Electric Lamps and Supplies Ltd. and in 1940 became Sales Manager. Later he became a Director of Siemens Electric Lamps and Supplies Ltd. and also of Siemens Brothers and Co., Ltd. He has twice been Chairman of the Council of ELMA and was for two years President of ELFA.

Trade Notes

Allom Heffer and Co. Ltd.

On June 1 a new company was formed in the name of Allom Heffer and Co. Ltd. This was brought about by the merging of part of the interests of Allom Brothers Ltd. and those of Heffer and Co. Ltd. The policy of the new company is to market a wide range of well-made contemporary fluorescent and tungsten lighting fittings as well as to continue to sell the special products which were marketed by Allom Brothers Ltd. The designs of the company's standard products will be under the direction of Mr. Noel Villeneuve, M.S.I.A., and a new comprehensive catalogue is being produced incorporating many new and interesting designs at competitive prices. Allom Brothers Ltd. will remain as the manufacturing organisation and they have recently opened a new factory. The head office of the new company is at 17, Montpelier Street, Knightsbridge, London, S.W.1 (Tel. KNIghtsbridge 6897/8), to which address all enquiries should be directed.

Harris and Sheldon (Electrical) Ltd.

The "Meico" range of cold cathode lighting fittings previously manufactured by Micramatic Ltd. has been taken over by Harris and Sheldon (Electrical) Ltd. and is now made at the main factory in Birmingham.

Miscellany

'Light and Lighting' Representative

Mr. Harold W. Thacker, Orchard Chambers, Bilston, Staffs (Bilston 42158), has been appointed to represent *Light and Lighting* in the Midlands.

'Sound and Light' spectacles

It has been announced that a "Sound and Light" spectacle is to be held at Greenwich Park during August and September. The display will be centred upon The Queen's House and the Royal Naval College, with the audience in the natural amphitheatre below the observatory in the park. Opening date is August 1. The display is sponsored by the *Daily Telegraph* in co-operation with Harold Holt, Ltd. The production will be by M. Paul Robert-Houdin, who has been responsible for many of the sound and light spectacles in France; it is understood that he will bring his own equipment and technicians from France.

Plans for the first British "sound and light" spectacle at Woburn Abbey have already been announced. The opening night is Bank Holiday Monday, August 5, at 9 p.m. There will be performances every evening (except Sundays and Mondays) until September 21. Price of admission is 4s.

ASEE Exhibition

A suggestion that foreign exhibitors be allowed to take part in future electrical engineers' exhibitions was not approved at a recent exhibitors' meeting. At the same meeting it was decided, in view of increasing demands for space, to develop that part of the exhibition housed on the first floor at Earls Court and to this end there will in future be a main staircase to the first floor from the body of the main hall.

Cutty Sark

On page 231 we show a photograph of the floodlit Cutty Sark at its final home in a dry dock at Greenwich. The dock lighting is by means of 48 2-ft. 40-watt Simplex fluorescent floodlight, and the lighting of the masts and yards is by 24 Simplex general purpose projectors. Lighting of special features such as plaques, tablets and the figurehead is by fittings supplied by G.E.C. Ltd. and Rowlands Electrical Accessories Ltd.

Brussels Exhibition

Troughton & Young Ltd. have been appointed official electrical contractors to the British Government Pavilion at the Brussels Exhibition 1958.

Capital available

£5,000 Capital or more available for Finance. Venture's Estab. Business's Stocks, etc. Any scheme considered. Write strict confidence, to Box 935.

Situations

Vacant

Ekco-Ensign Electric Ltd., 45, Essex Street, W.C.2, require (a) Young LIGHTING ENGINEER for I.E. Dept., London; (b) LIGHTING ENGINEER to contact architects and consultants; (c) ELECTRIC LIGHTING FITTINGS DESIGNER. Apply Senior Lighting Engineer.

Corporation of the City of Aberdeen Lighting Department. Applications are invited for the post of TECHNICAL ASSISTANT in the above Department at a salary within Grade C.S.6 (£565-£610). Particulars as to the appointment may be had from the Superintendent of Lighting, 262, King Street, Aberdeen, with whom applications should be lodged on or before August 17, 1957. J. C. Rennie, Town Clerk, Town House, Aberdeen.

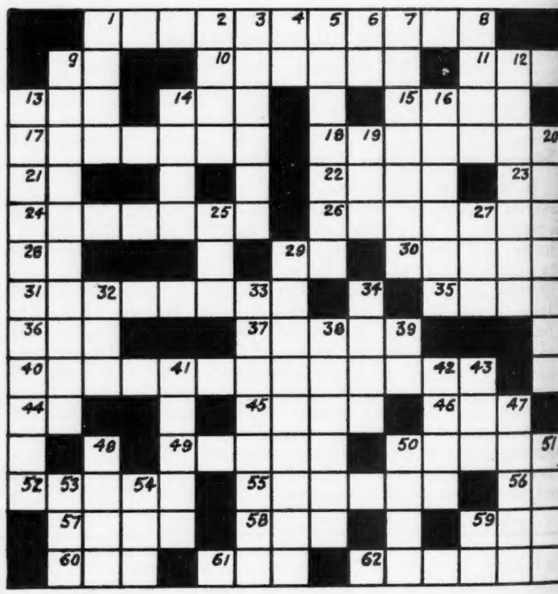
Philips Electrical Ltd. A vacancy exists in the Lighting Division of this company for a COMMERCIAL ASSISTANT. Applicants should be between 25/35 years of age with experience of commercial correspondence, enquiries and quotations in the field of lighting fittings and accessories. The appointment is in our London headquarters and carries an attractive salary and other benefits. Applications giving brief details of age, qualifications and experience should be addressed to the Personnel Officer, Century House, Shaftesbury Avenue, W.C.2, quoting ref. 118.

POSTSCRIPT By "Lumeritas"

RECENTLY, in this journal, yet another name for the British unit of illumination has been added to the list of those proposed during the past few years. The excuse this time is that some architects are confused by "lumens per square foot" and make confusion worse confounded by abbreviating this descriptive expression to "lumens." On more than one occasion I have said I think there is a good case for a short name for this unit, though not for a return to that misbegotten monstrosity "foot-candle." In this matter, however, the luminaries of the lighting world are apparently inert. Of course, the problem ought to be solved by the universal adoption of one system of units—the one with which the neatest name is already associated. However, man being anything but *homo sapiens*—which he is supposed to be—most of us will depart this life before that happens!

THE sound and light spectacle to be presented at Woburn Abbey on Bank Holiday night and, subsequently, on five nights weekly until September 21, is an enterprise which I hope will prove as successful as the "Son et Lumière" spectacles have been in France. Our country is rich in historic and beautiful buildings whose story could be presented on the site in this dramatic and fascinating way, though not all of them are accessible easily enough to attract a worth-while number of visitors.

BELOW is the last of my little devices for giving your "little grey cells" a change of occupation during the holiday period. And here follows the solution of the July puzzle. *Across*: 1, Bright Dip.M.I.E.S. 9, Quill. 10, Lunar. 11, Light. 13, Odds. 15, Assume. 17, And. 19, Deem. 20, Anaima. 21, Lighting. 23, Inca. 26, Acumen. 30, Ophthalmologist. 34, Pair. 35, Sti. 37, Optician. 40, Tea. 41, Plano. 44, User. 45, Ancon. 47, Architect. 48, Yea. 49, Saucy. 50, Lone. *Down*: 1, Bunsen. 2, Illuminations. 3, Glim. 4, Data. 5, Plod. 6, Mud. 7, Indict. 8, Ease. 12, Gena. 14, Tangential. 15, Adagio. 16, Search. 18, Nuit. 22, Goal. 24, NPL. 25, Plaid. 27, Coon. 28, Mist. 29, Ester. 31, Apt. 32, Mic. 33, Oriency. 36, Apply. 38, Poets. 39, Arch. 42, Aura. 43, Into. 45, Arc. 46, Oil.



ACROSS

1 Blinds may do this.
9 A promise may be so qualified (*init.*).
10 A matter of small quantities.
11 Frequently limited and soon dissipated just now (*init.*).
13 A lighting company? Mais oui : of a kind.
14 Worth it means and a lighting worthy.
15 This suit will do for the "fireworks" if you spoil it.
17 Now is the time for this.
18 A V.I.P. in the "lighting world" even without his foot and his girl-friend.
21 Given enough of this you might get "lit-up"!
22 Indian wild buffalo.
23 A good beginning to a nice girl's name.
24 Creator of darkness, it might be said in a Persian garden.
26 Maybe what Swift called "serious philosophical lucubrations."
28 Not far to go in sol-fa for this.
29 Why guillotine the vet. for such a trifle?
30 Who resects dissects leaves the bodies intact.
31 If this, "the lady's not for burning."
35 Medium : intermediate.
36 Scotch and applicable to a scotch.
37 Tho' not abominable snowmen they make tracks.
40 What its light is to a point source.
44 Several universities have one (*init.*).
45 Your local "pub" may be.
46 This delicacy may be extracted from steel.
49 What you may drink in New York without consuming it.
50 By some of these, e.g., light and eyes, we see.
52 Not only the end of **13** down but the end of an alphabet.
55 This may be said of parts of some luminaires.
56 Good lighting of course (*init.*).
57 When you come to the lane put "the cart before the horse."
58 May sound like "eyes" and has much to do with them.
59 Names an important symbol.
60 May be the answer to a bachelor's prayer.
61 A Mediterranean island.
62 Don't dislocate the lighting vocabulary with this.

DOWN

1 Across though down.
2 Tho' not sore may occasion some pain.
3 Ordained—said a poet—to shed light upon light.
4 The sodium-free part of a Mediterranean volcano?
5 Safeguards some lamps as well as Mayflower II.
6 An I.E.S. venue biennially (*init.*).
7 Sometimes involved in the production of light lighting fittings.
8 Different.
9 Since glass is this, large windows may not be an unmixed blessing.
12 Some give rise to concrete and colourful complaints.
13 Concerned only with brightness differences.
14 Think.
16 It is always in the same place.
19 Lighting may exemplify this.
20 Just the thing for heat-wave apparel.
25 Lighting is a visual one.
27 Tho' wintry is welcome in summer.
29 Inquisition victims.
32 Forenamed Jack, but Tom, Dick and Harry may put it on **12** down.
33 An offering of words and music.
34 What the unwary walker did on **27** down.
38 Wild goats.
39 A London postal district.
41 A headless headdress?
42 Often felt for **11** across.
43 Half coated yet may be long coated.
47 A heady state in a fever.
48 A popular source of light and sound spectacles.
50 Beheaded lumen (anag.).
51 A kind of Lily-wort.
53 Where a royal lady may dwell.
54 May differentiate a bag.
59 A name of the ancient Egyptian Sun-God.

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